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RUDIMENTS OF CHEMISTRY

D. B. REID

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RUDIMENTS

OF

CHEMISTRY.

WITH

ILLUSTRATIONS OF THE CHEMISTRY OF DAILY LIFE.

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"Were the great truths which Chemistry unfolds in reference to the phœnomena of Daily Life taught universally in Primary Schools, there is no branch of Practical Science, Agriculture, Arts or Manufactures that would not afterwards profit by the Key thus presented in early life to the Nature and resources of the material World."

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PREFACE.

THE object of this work is to facilitate the introduction of a Course of Chemistry, as an elementary branch of education, in all schools and academies, and to lay a foundation for the young pupil's future progress in Science, and in the more important of its practical applications in the economy of daily life and the useful arts, by awakening his mind to the nature of the material world in which he is placed.

Chemistry occupies a position altogether peculiar, when considered as a branch of general education, from its practical relation to the materials that affect man every moment during the whole period of his existence. No one can study the phenomena of respiration, the nature and varieties of atmosphere to which the human frame is exposed, the theory of combustion, the communication of heat, the production of artificial light, the purification of water, the evolution of poisonous gases and other deleterious impurities, or any portion of the infinite variety of facts which this science has pointed out or explained, without seeing the important position which it holds with respect to the general economy and management of the means provided by the Author of nature for the existence of man.

Every one, in reality, is more or less a practical chemist, whether he shall study chemistry systematically or not; and it becomes a question, therefore, how far it may be possible to introduce, as a general branch of education, a course of such select illustrations as may enable all to become familiar with the facts connected with this science which influence the wants and comfort of daily life. Such courses would have the advantage of awakening the mind of

the young pupil to a more precise understanding of the nature of the material world in which he is placed, and lead him to observe with a philosophic eye many of the phenomena of nature and of art, which, under ordinary circumstances, he altogether overlooks, from the want of a proper key.

They have not been recommended without a proper trial of their practicability. Several years ago, courses were given to upwards of one thousand persons, from different schools and academies, with a view of determining details; and it is submitted, that, were arrangements made for their general introduction, the expenditure of a very moderate sum in each school would be sufficient to provide apparatus for illustrating the more important and essential points in chemistry, connected with the general preservation of health, the use and application of fuel, and the various departments of this science that are continually forced upon the attention in every class of society. It is not contemplated to engage in such preliminary courses with complicated instruments, but to render familiar the use of more simple apparatus, such as there will be no difficulty in experimenting with, after a little practice, while, at the same time, it will be sufficient for all the illustrations required.

In all the schools where such trials have hitherto been made, the pupils entered eagerly into the prescribed exercises. These were evidently, when properly arranged, congenial to their inclinations and adapted to their capacities. One hour a-week, for one session, would be sufficient to lay a good foundation, were no more time granted. And when the illustrations shown by the teacher are conjoined with a system of practical lessons in testing with flat-glass apparatus, the operations in which the pupils engage individually afford a mental exercise of great importance, while they train in early life those that perform them to habits of precise and accurate observation. The union of a certain amount of practice with the theory of the subjects taught, however simple the arrangements by which all the pupils are enabled to join in this department, has been found of great importance in carrying these views into effect. The pupil, as Chaptal has well observed of those who engage in experiments, then sees in his practice the confirmation of all that is told him; he refers all that is said to all that he does; he compares the theory with his own operations, and in a manner identifies it with them.

Again, such courses would not only be important in econo-

mising the means and increasing the comforts of the poor, but prove equally advantageous to other classes of society. Further, they have become essential for young persons intended for professions where a knowledge of physical science is necessary, as, from the great progress now made in all its branches, without some previous training in elementary schools, it would be as impossible to expect the medical man, the engineer, the architect, the manufacturer, and all who are professionally interested in science, to obtain that amount of information from the usual course of education which is now required, as it would be for any one to maintain a proper rank as a scholar or a mathematician, were he never to enter upon the study of classics or mathematics till he should join a university. Even now, in some professions, it is observed that the period of professional education is not adapted to the present state of science; and if elementary instruction, in some branches at least, be not provided systematically in schools and academies, an extended period must be allotted to it at a future time, which must bear heavily on the means and resources of the advanced student, or college and university courses must be kept at a low level, compared with the ground they would take, were professors not compelled, as they too often are at present, to begin their courses with the most simple and elementary facts, which might be taught more advantageously before the pupils come to them.

Chemistry, accordingly, may be affirmed to have claims upon general attention, which no other branch of physical science presents; and it is also to be considered, from the cognisance which it takes of the composition of matter, as the basis of other branches, which can be associated with it afterwards in each peculiar seminary of education, as local circumstances may determine.

Were the above plan carried more extensively into operation, a great mass of information, in reference to the nature and capability of the materials of which the globe is composed, and of the productions of art, confined among a comparatively small number at present, would, in the course of a very few years, be much more generally diffused throughout the country; and, besides the direct advantages that would be gained in this manner, many other valuable results would be obtained, particularly a more specific knowledge of the nature of the action of external agents upon the human frame; whence additional and more willing assistance might be calculated on in carrying out the details of all public measures for the

improvement of health. especially in that class of society whose want of means and of inclination render them most obnoxious to those causes of disease which can be alleviated or removed by care and attention. Nor ought it to be forgotten, that these means would establish, at the same time, opportunities which might enable emigrants to acquire a knowledge of numerous facts, which must be highly valuable to them after they leave their native country, though, perhaps, the establishment of a few local schools for this purpose, in the principal ports from which they embark, would also be desirable.

The leading outlines of the plan recommended were fully detailed, a few years ago, in Chambers's Journal,* and I beg to refer to that work for further remarks on the subject.

In using this treatise, the teacher is recommended to show such experiments as his facilities may permit, from the very commencement of his course; and practice will soon enable him to avail himself of numerous adjustments which may not at first occur to him. He ought also to endeavour to arrange a small museum of specimens, commencing with those tests and chemicals mentioned in the last chapter. The frequent use of the chemical abacus described in treating of the particles of matter, will be found materially to assist the general student in ascertaining the precise nature of numerous chemical operations, more especially when he has not the advantage of frequently seeing experimental illustrations.

* See Nos. 226 and 226.

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RUDIMENTS OF CHEMISTRY.

CHAPTER I.

INTRODUCTION.—NATURE OF CHEMISTRY.

1. This globe presents a vast variety of materials to view, having many different properties. By these they are distinguished from each other, and adapted for the various purposes they serve in the general economy of nature, and in supplying the wants of man. A knowledge of their properties has been gained by the general experience of mankind, gradually increasing in each successive generation, and also by the discoveries that have so often attended the investigations of men of science who devoted their time to such inquiries.

2. The term Physical Science is usually employed to signify the knowledge of the material world, which has been obtained in the above manner, namely, by observation and by experiment.

3. For the convenience of the student, as well as with the view of providing a clear and systematic classification, it has been customary to consider the facts that have been discovered in various points of view, and to arrange them under different heads or departments. Hence, in particular, have arisen the two great branches of Natural Philosophy and Chemistry, which may be said to constitute the basis of every department of physical science, whether it refer to the animal, to the vegetable, or to the mineral kingdom.

4. Natural Philosophy takes cognisance of all those properties of matter in which the form and the stability or motion of matter come into play. The sailing of a boat, the movement of a cannon-ball, the working of a machine, the construction of a building, the alteration in the form of a piece of wood,

stone, or marble, as induced by mechanical means, all come within the province of Natural Philosophy. The stability of bodies, motion, its production and direction, and the effect of any impetus produced by one mass of matter acting on or striking another, are always the great objects of consideration.

5. But in Chemistry a very different view is taken. The properties of the minute particles of matter are investigated, and the manner in which the particles of one kind of matter affect the particles of other bodies, when they are intimately mixed with each other.

6. In the department of Natural Philosophy, the materials or masses that may be the object of experiment and observation present the same general characters before and after they have been observed or made the subject of experiment. The marble that is dug out of the ground is still marble, whether broken into fragments by a rude blow with a hammer, or fashioned into a bust or statue by the chisel of the sculptor, a mechanical change solely having been effected.

7. In chemical action, however, this is not the case; the matters that come into play form more or less a substance having a new appearance, and heat, light, electricity, and magnetism, are often and sometimes all developed in the same experiment. When a piece of coal burns, a chemical action takes place between its particles and those of the air; the coal in a great measure disappears, and the air in contact with it acquires new properties, becoming fatal to animal life, and incapable of supporting the combustion or burning of more coal, while heat and light are largely evolved. All this arises from the minute particles of the coal affecting the minute particles of the air, the greater portion of the coal producing matters that are no longer visible, but which are thin and attenuated like the air, however different they may be from it in other respects.

8. If coal be heated without access of air, another series of chemical changes occur; gas, water, tar, ammonia, and coke, are the result.

9. Again, sugar and salt are dissolved by water, the particles of the fluid uniting with those of the solid; and by mingling various substances, not only are heat, light, and electricity evolved, but solids often become liquid or gaseous, while liquids become solid or gaseous, and gases often pass to a liquid or solid form.

10. The colour, density, lustre, tenacity, and other properties of bodies acting chemically, are frequently so entirely changed, that we cannot with the eye alone recognise in the products the original materials out of which they may have been formed; if sand and soda be heated in a furnace, the particles of the

one unite with those of the other, and melt into a transparent glass.

11. A change of properties, then, is the grand and leading character of the operations of Chemistry, not a change of motion, place, or figure, as in Natural Philosophy.

12. But what are the particles of matter? Has any one ever seen them? Can we take any one out from any mass of matter, and examine it by itself? Man has not hitherto been able to answer the former question, nor has he powers of vision sufficiently acute, nor instruments sufficiently delicate, to enable him to pick out a particle from any mass of matter, and show it by itself. The particles referred to here are not small portions such as would be termed particles in ordinary language, but the minutest portions which it would be possible to obtain were the subdivision of these ordinary particles carried to the greatest extent of which they are susceptible. The progress of Chemistry has pointed out a series of facts connected with the proportions in which bodies combine, which have led universally to a belief in the existence of very small *particles* or *atoms*, by the union of which all masses of matter are composed. And so excessively minute are they supposed to be, that it is considered as impossible for any one to recognise the individual atoms in any mass under observation, as it would be for him to distinguish with the naked eye the various plants, shrubs, flowers, and their leaflets, that may cover the face of a very distant mountain, however distinct its characteristic outline may appear. They are so minute that they are concealed from his imperfect view, though he may see the matter of which they are composed. But were he to acquire a more powerful vision, he would doubtless see every particle in its appropriate place, as palpably as a near inspection would show him the shrubs, the flowers, and the leaflets on the mountain.

13. The atoms, then, which compose masses of matter, may be regarded as the more immediate creation of the Deity, the masses into which they are now united having been produced by the circumstances to which they have been subsequently exposed, and the number and nature of those associated together. They have unquestionably been created with a view to the various purposes to which they have been applied by man; and hence we see, in the most striking point of view, that even in all those inventions which man has made, he has still employed materials that may be said to have been created for such purposes by the Author of Nature. And, in a chemical point of view, were he able to procure a magnifying glass of sufficient power, he might then be able to trace the progress of individual particles in all their fluctuating changes, recognising them in

all their new and varied forms, however different to the naked eye the masses may appear in which they are contained.

14. Again, these atoms or particles are not considered as susceptible of any change, however varied the appearance of a mass of matter may be, owing to the manner in which they are grouped together. They may constitute a thin and invisible gas like the air that we breathe, a dense and ponderous solid, a cloud, or a mobile liquid, according to the mode in which they are associated with each other. What matter is more familiar to us in many different conditions than that which constitutes ice, water, steam, and the vesicular vapour of which clouds are composed? Neither can they in anyway be destroyed by any power that man possesses, or which is known to operate at the surface of the globe. They may appear and disappear before the naked eye, but they still exist as essentially in the thin and invisible gas as in the most ponderous solid. Newton well expressed the opinion that is now prevalent when he said that he considered it probable "that the Author of Nature in the beginning formed matter in solid, massy, hard, impenetrable particles, of such sizes and figures as most conduced to the end for which he created them, and that these primitive particles are incomparably harder than any porous solids composed of them, so hard, as never to wear away or break in pieces, no ordinary power being able to divide what had been made one in the first creation."

15. These are the particles that produce chemical action, when different kinds unite together or are separated from one another. So small are they, that individually they are invisible, and yet so countless are the myriads, in which they are gathered together, that they constitute the air, the earth, the ocean, and everything material that is observed upon the globe. So curiously, also, are they constituted, that they never change their chemical arrangements without the evolution or absorption of heat, light, or electricity. Grand and majestic as the great and most imposing phenomena of nature are, still, whether we look at the thunder-storm, at the hurricane, or at the volcano, it is to the action of these particles that all must be more immediately attributed.

16. If we turn from the mineral to the vegetable and animal kingdoms, there again we shall find the atoms in incessant action, modified no doubt by the peculiar apparatus which, in one point of view, a tree or the body of an animal may be considered, the different structures that are there observed being made from the food by a chemical action—from materials which were dead, and which, in the progress of time, when death takes place, return again to their kindred dust. And if

in the productions of the animated world a peculiarity of structure be observed, which is never witnessed in the mineral kingdom, this arises from the various particles out of which they are constructed being presented to each other in the living frame, which may be termed, so far as the mere chemical relations of the materials composing it come into play, an apparatus constructed by the Deity himself, and in which all the particles must take that peculiar impress and arrangement that depends upon the circumstances in which they meet, just as the texture of any fabric or work of art indicates the peculiar operation or machinery to which it may have been previously subjected.

17. But in what way is Chemistry useful, and what purposes does it serve in the ordinary affairs of life? Chemistry teaches the nature and composition of bodies, and many of their most important properties which it is desirable for man to know. It teaches him the nature and qualities of the air that he breathes, of the water which he drinks, of the food upon which he lives, of the apparel with which he is clothed, of the earth upon which he treads, and numerous changes of which they are susceptible, all conducive to his advantage according to his skill in the chemical changes to which they are subject. In short, all bodies with which man is acquainted being constantly subject to a variety of chemical changes, and in numerous cases prepared entirely by chemical processes for the purposes to which they are applied, no phenomena are more continually forced upon his attention in the works of nature, or in the operations of art, than those which arise from chemical action. But on other occasions they present characters that are valuable from the manner in which they indicate danger, and forewarn him of circumstances that might otherwise render him liable to injury or death; as, when the extinction of a burning candle by the atmosphere of any old well or pit, informs him that it might prove fatal to descend there, the cessation of the chemical changes that accompany the burning of the candle, being proof that the air in the old well or pit is as unfit for respiration as it is for combustion.

18. Again, Chemistry is a source of unceasing interest from the singular nature of the facts which it discloses, and the endless purposes to which they may be applied. It has explained the composition of air, earth, and water, and examined, under the varied action of heat, light, and electricity, the powers and properties of different kinds of matter. And how well has man been repaid for his toil and labour in such investigations! Thousands of discoveries have lent their aid in advancing the tide of civilisation, and in adding to the comforts of life; the

true theory of combustion has been unfolded; and in trying the properties of matter by fire, the nature and energies of steam have been disclosed; while the investigation of various subjects, in some cases not very promising in their first aspect, have afforded the most gratifying results, as in the examination of the chemical qualities of smoke, which has given rise to gas-lighting, and furnished those products that led to the manufacture of India-rubber cloth and other operations, in which numerous establishments are now actively employed.

19. Among the chemical arts that constantly engage the attention of mankind, a glance at a few of the most important will at once show the great extent and importance of a knowledge of Chemistry.

20. Baking, brewing, distilling, and all the operations by which food is prepared from the condition in which it is furnished by nature, are all in general a series of chemical processes. The manufacture of bricks, pottery-ware, porcelain, and glass, of mortar and cements, the extraction of metals from their ores, and the formation of alloys and amalgams, the operations of bleaching, dyeing, and calico-printing, the preparation of soap, soda, acids, alkalies, and of a never-ceasing variety of products usually termed chemicals, in consequence of their generally being prepared by those who have some skill in chemical processes, are all operations that come under this extensive science.

21. Let us look more minutely to the importance of any one of these chemical arts. Take, for example, the manufacture of iron:—"A piece of iron-ore, in the condition in which it is usually met with in this country, presents nothing but a dark stony-looking mass, uninteresting to any one unacquainted with its composition, and ignorant of the power which Chemistry possesses over it. Subject it, however, to the operation of the blast furnace, and the metal immediately appears; and how varied are the purposes to which it is applied—how many are the forms which it may be made to assume! What are the tools with which the mason, the smith, and carpenter work—those who contribute so large a share to the comforts of life in every civilised community? Iron is the element of which they are composed; iron is the element by which they are made. What are the instruments with which the miner penetrates into the bowels of the earth, and acquires dominion over the mineral kingdom? Are not the pick, the axe, and the spade, made of the same material? In the hands of the agriculturist, it forms the plough and the pruning-hook. With the soldier, it passes into the sword, the gun, the pistol, and numerous other instruments of attack and defence. But let us turn again, and we see it in the

cutting-knife of the surgeon, mitigating, by its severe yet wholesome operation, the most dreadful maladies to which humanity is subject. Look at it in the steam-boat, contending with wind and tide on the ocean; and in the steam-coach, see how it outstrips the fleetest horses! Look to it in the little needle employed in the finest and most delicate embroidery. Look again, and you see it in the beam of the mighty steam-engine, wielding with its single arm a power superior to the united energies of a thousand men. It forms the bolts that bind together the timbers of every vessel that leaves our shores, each in itself a monument of art, a moving citadel; it forms the magnet that guides their path across the trackless ocean, and the anchor that stays them in the storm. In many ships as they are now constructed, this metal may often be observed replacing even the very timbers that are usually employed. It forms the ink, and now even the very pen, with which we write. In the printing-press it is still more conspicuous, assisting in that great engine for the diffusion of knowledge. And in the watch-spring, it enables us to count the fleeting moments as they pass away. But volumes would be required to tell all the purposes to which it is applied; and still we cannot forget that it can neither be extracted from the ore, nor applied to any of these objects, unless by the powerful aid of chemical action. And Chemistry abounds with facts such as these.

22. It has indeed thrown a new light on the phenomena of nature, and explained a thousand mysterious operations, of which formerly we were completely ignorant. Chemistry, also, in unveiling the natural operations that are carried on at the surface of the globe, has made us acquainted with numberless agencies, whose continued action is essentially necessary to preserve the order of nature, and affords us a new display of that stupendous power and wisdom that commanded order out of chaos, and imposed upon every atom powers as necessary to the present state of nature, as the regularity of those movements that keep the mightiest orbs balanced in their spheres, so that, amidst incessant changes, no jarring element is allowed to disturb the harmony of the whole. There is no science which is more admirably adapted to form a pleasing and an interesting pursuit. He who is acquainted with Chemistry has a new key to explain the works of nature; nor can he walk abroad without finding in all her operations, and in all the products of the material world, a new source of important and interesting instruction."*

* From the Study of Chemistry, by Dr Reid. See Chambers's Journal.

CHAPTER II.

GENERAL OBSERVATIONS ON MATTER AND CHEMICAL ACTION.

23. Matter is observed at the surface of the globe in four very different forms, namely, in the solid, liquid, gaseous, and vesicular form. Earth, water, air, and clouds, present familiar examples of these conditions.

24. SOLIDS are particularly distinguished by the comparative rigidity of their texture, opposing considerable resistance to any attempt that may be made to reduce them into smaller parts. They are in general the heaviest bodies observed at the surface of the globe.

25. LIQUIDS are distinguished by the extreme mobility of their particles, these moving upon each other, changing their relative position, and producing currents from numerous causes that have no such effect on solids.

26. GASES are thin and attenuated compared with solids and liquids, and are still more mobile than water and other liquids. Vapours constitute a variety of gases, differing from them, as steam differs from atmospheric air, in so far as the one is condensed by cold into water, while the other is not affected in this manner by any degree of cold to which it has hitherto been exposed.

27. VESICULAR VAPOURS present matter in a peculiar condition, into which many vapours pass, under circumstances which have not hitherto been satisfactorily explained. Clouds present a familiar variety of vesicular vapour.

28. A number of substances are capable of appearing in all these forms; as water, which can be frozen into ice, converted into steam by boiling, or made to present the appearance of vesicular vapour when the steam is allowed to come in contact with the air. Other bodies cannot be made to present such changes; but where the texture is not altered or destroyed by the application of heat or cold, it is considered that it would be possible to cause similar changes in all bodies by the action of more intense heat and cold than can be at present produced.

29. In a chemical point of view, all bodies, whether in the solid, liquid, gaseous, or vesicular form, are regarded more especially as being *simple* or *compound*.

30. Any matter from which nothing different from itself can be obtained is considered simple, and termed an *element:*

thus sulphur is called an element, because, do what we may with it, nothing different from sulphur can be procured from it. *Compounds* consist of different kinds of matter which may be separated from each other, as salt-water, from which the water may be separated by boiling, when the salt is left.

31. All masses of matter are composed of small particles (see par. 12, &c.), and these being considered indivisible, are termed *atoms*. They must be exceedingly small, though their exact size is unknown, as a single grain can be divided into many millions of parts. To illustrate this:—Put one grain of sulphate of iron, which contains only about a fifth part of iron, into fifty ounces of water, and add a few drops of a solution of the ferrocyanate of potassa. Every portion of the water is coloured by the ferrocyanic acid, one of the ingredients in the ferrocyanate acting on the iron. A solution of the ferrocyanate is prepared at once by pouring upon it in powder ten times its bulk of water.

32. The particles of a mass of any element are similar to each other, and contain only one kind of matter. But the particles of compounds contain two or more dissimilar particles.

33. Masses of matter are *compressible*, *divisible*, and *porous*, but particles are considered *incompressible*, *indivisible* (unless in the case of compounds), and *destitute of porosity*.

34. All particles of matter are subject to the influence of heat, light, electricity, and magnetism, and possess also powers of *attraction* and *repulsion* for matters of the same and also of a different kind, according to the circumstances in which they are placed. The precise cause of these powers of attraction and repulsion is unknown; all that can as yet be stated on this point is the bare fact that matter has been so constituted by the Author of Nature. It is well ascertained, however, that there is a very intimate connexion between chemical action and the development of heat, light, electricity, and magnetism, as the particles of matter, in assuming new arrangements in chemical operations, often evolve heat, light, and electricity, while the latter can always be made by various arrangements to develop magnetism in iron. It is also equally known that heat, light, electricity, and magnetism, can in their turn produce chemical changes, when they are brought to act on the particles of matter.

35. By the action of these powers or forces of attraction and repulsion, all changes in the material world are regulated; all bodies, even those that may at one time present a strong and unyielding texture, are subject to decay from the separation of their individual parts, while new attractions operate and cause them to assume new forms.

36. In studying the properties of matter, it is important to recollect that these are *primary* and *secondary*.

37. The *primary properties* are observed in all kinds of matter. They include *extension*, *impenetrability*, *inertia*, and *indestructibility*. Matter is obviously extended, and it is also indestructible by any operations to which it can be subjected, in the ordinary course of circumstances observed at the face of the globe. By impenetrability it is intended to signify that no portion of matter can penetrate into the space that is occupied by another at the same moment. The term inertia refers to the fact that matter cannot *of itself* begin to move, or assume a quiescent state after being put in motion.

38. The *secondary properties* of matter constitute those by which one kind of matter is distinguished from another; and they include also the power of attraction, and the relation which matter bears to heat, light, electricity, and magnetism. Of these, the most important is *attraction*, which is termed *gravitation* when it operates between masses of matter.

39. All kinds of matter tend to attract each other, mass to mass, and particle to particle. When a stone is lifted from the ground by the hand, the mechanical effort made by the hand overcomes the force with which the stone is attracted by the earth and retained at its surface. When it is no longer supported by the hand, it falls, or is drawn down to the ground by the attractive power of the earth.

40. Even air is attracted by the earth, and presses upon each square inch of its surface with as much force as a weight of 14·6 lbs.

41. When particles of the same kind of matter attract each other and unite, a mass having the same properties as these particles is formed, and then the term *cohesion* is used to express the power of attraction operating between them. But when particles of different kinds of matter unite, the new particles thus formed have properties in which they differ more or less from those substances by whose union they are formed, and the term *chemical attraction* or *affinity* is then employed.

42. No substances can act chemically with each other which are not mixed together in the most intimate manner. Mixture is very different, however, from chemical action; sand and water may be mixed intimately together without producing any chemical change, but if salt and water be mingled together, the salt is dissolved by the water, combining with it and disappearing, while the water acquires a salt taste.

43. By heat, light, and electricity, many kinds of chemical action may be effected, which do not take place by mere mixture.

44. All *chemical action* consists in combination or decom-

position. *Combination* signifies the union of particles of different kinds of matter, as when sugar unites with water. By *decomposition* is understood the separation of particles of different kinds of matter which had previously been united, as the separation of salt and water from sea-water.

45. SOLUTION.—Suspend a piece of aqueous sulphate of copper (common blue vitriol), in thin gauze in a beer-glass or glass jar full of water. The particles of both combine, and form a stream of blue fluid, which descends from the points where they are in contact. The solid is said to be *dissolved*. The compound is called a *solution* of the solid.

46. Put a piece of an iron hoop, a few inches in length, into any glass vessel, cover it with water, and pour upon it aqueous sulphuric acid, equal to 1-6th of the bulk of water employed; so powerful is the chemical action exerted, that the particles of acid and of oxygen separate all the particles of iron from each other and combine with them; the hydrogen, the other element of the water, is disengaged in the gaseous form.

47. PRECIPITATION.—Fill a beer-glass full of water, and dissolve in it ten or twelve grains of bichromate of potassa (a salt composed of chromic acid and potassa), adding it in powder. Dissolve as much acetate of lead (common sugar of lead), consisting of acetic acid and oxide of lead, in another similar glass with water, filtering the solution obtained, if it be turbid. On mixing the solutions, the chromic acid and oxide of lead combine, and produce a solid compound which falls down, and is said to be *precipitated;* the acetic acid and potassa unite, and remain in solution.

48. EFFERVESCENCE.—Put a table-spoonful of carbonate of soda (common soda) into a large beer-glass, cover it with water, and pour upon it aqueous sulphuric acid (oil of vitriol) as long as gas escapes. The chemical action consists in the union of the particles of the sulphuric acid and the particles of the soda, and the separation of the carbonic acid, the other ingredient in the carbonate of soda; it is expelled with *effervescence:* this term is applied whenever gas escapes rapidly from any liquid.

49. EVOLUTION OF HEAT AND LIGHT.—Mix intimately two or three grains of chlorate of potassa with an equal weight of sugar, and touch the mixture with a glass slip previously dipped in aqueous sulphuric acid. It causes a compound of chlorine and oxygen to escape from the chlorate, which immediately inflames the sugar.

50. NEUTRALISATION.—This term denotes the complete loss of properties that frequently attends combination. For example: acids render the blue colouring matter of cabbage red, while alkalies turn it to a green; but if the acid be combined

with the alkali in certain proportions, the blue is not turned either red or green. It is not affected at all, and the compound is said to be *neutral;* the acid and alkali are said to have *neutralised* one another, each having lost the characteristic property mentioned. To show this experiment, take two glasses containing water tinged with vegetable blue; and after rendering one red by a little sulphuric acid, and the other green by common soda, mix small portions of these liquids in another glass till the blue colour is restored, by the acid in the one combining with the alkali in the other.

51. SATURATION.—This term is employed to denote the largest quantity of one body that can combine with a given weight of another; as when water is said to be *saturated* with salt, or has taken up as large a quantity of any salt as it can dissolve.

52. All bodies do not act chemically with each other; if we shake sand and water in a bottle, whenever the agitation ceases the sand falls: the water has no chemical action with it.

CHAPTER III.

ELEMENTS OF WHICH THE GLOBE IS COMPOSED.—CHEMICAL EQUIVALENTS, NOMENCLATURE, SYMBOLS, DIAGRAMS, THE CHEMICAL ABACUS.—GASEOUS ELEMENTS AND COMPOUNDS.

53. All bodies which unite chemically tend to combine in certain fixed or definite proportions. The numbers representing these proportions are called *chemical equivalents.* Thus, one pound of hydrogen combines with eight pounds of oxygen: 1 therefore is the chemical equivalent of hydrogen, and 8 that of oxygen.

54. When bodies unite in more than one proportion, the proportion in each successive compound is represented by a multiple of that in the first compound, as in the following example:—

	Nitrogen.		Oxygen.		
Oxide of Nitrogen, .	14·2	+	8	=	22·2
Binoxide of Nitrogen,	14·2	+	16	=	30·2
Hyponitrous Acid, .	14·2	+	24	=	38·2
Nitrous Acid . .	14·2	+	32	=	46·2
Nitric Acid, . .	14·2	+	40	=	54·2
Atmospheric Air, .	28·4	+	8	=	36·4

55. The equivalents of compounds are found by adding the equivalents of their elements; thus, 22.2 is the equivalent of oxide of nitrogen, consisting of 8 oxygen and 14·2 nitrogen.

56. The following list comprises the names of the elements of which the globe is composed, so far as they are known, with their symbols and chemical equivalents. Hydrogen being taken as a standard of comparison, the equivalent number of each element is ascertained by examining that quantity of it which combines with a given quantity of hydrogen. Where any substance does not combine with hydrogen, its equivalent is ascertained by finding out in what quantity it combines with the equivalent quantity of any other substance which can unite with hydrogen. The following equivalent numbers represent those generally adopted, and are to be regarded in some cases only as approximations. Phosphorus is represented by 31·4, and antimony by 129·2, by some chemists. Elements with † prefixed have been very imperfectly described.

Symb.	Name.	Equiv.	Symb.	Name.	Equiv.
*H	Hydrogen,	1	Z	Zinc,	32·3
*C	Carbon,	6·12	As	Arsenic,	37·7
*O	Oxygen,	8	Zr	Zirconium,	33·67
*B	Boron,	11	K	Potassium,	39·2
*N	Nitrogen,	14·2	Sr	Strontium,	43·8
*S	Sulphur,	16·1	Sb	Antimony,	64·6
*P	Phosphorus,	15·7	R	Rhodium,	52·2
*F	Fluorine,	18·7	Mo	Molybdenum,	47·9
*Cl	Chlorine,	35·5	Ce	Cerium,	46
*Se	Selenium,	40	†La	Lantanium,	?
*Br	Bromine,	78·4	†Dd	Didymium,	?
*I	Iodine,	126·5	Cd	Cadmium,	55·8
Si	Silicum,	22	Pd	Palladium,	53·35
L	Lithium,	10	Sn	Tin,	58·9
Al	Aluminum,	13·7	Th	Thorinum,	59·6
Mg	Magnesium,	12·7	Ba	Barium,	68·6
G	Glucinum,	26·5	Bi	Bismuth,	71·5
Ca	Calcium,	20·5	W	Tungsten,	94·8
Na	Sodium,	23·5	Pt	Platinum,	98·84
Co	Cobalt,	29·5	Pb	Lead,	103·7
Ni	Nickel,	29·5	Ag	Silver,	108·3
Fe	Iron,	28	Ta	Columbium,	184·8
Mn	Manganese,	27·7	†Nb	Niobium,	?
Cr	Chromium,	28·19	†Pp	Pelopium,	?
Ir	Iridium,	98·8	†Il	Ilmenium,	?
Cu	Copper,	31·7 ?	Hg	Mercury,	203
Ti	Titanium,	23·5	Au	Gold,	200
Te	Tellurium,	64·2	U	Uranium,	217·2
Y	Yttrium,	32·25	Os	Osmium,	99·7
†E	Erbium,	?	†Ru	Ruthenium,	?
†Tb	Terbium,	?	V	Vanadium,	68·5

57. The elements are arranged in this list in the order or sequence in which their properties, so far as they are enumerated in this treatise, can be most successfully studied.

58. The term *supporter of combustion* is often applied to oxygen, chlorine, iodine, and bromine, because many bodies burn with great facility when brought in contact with them in the gaseous state.

59. Hydrogen, sulphur, phosphorus, carbon, boron, and many metals, are termed *inflammables*, as they are so easily inflamed. These two terms, however, inflammables and supporters of combustion, are used in a less specific sense than formerly, as it has been found that two inflammables often give out heat and light during combination, so that in this case the one would require to be considered a supporter of combustion, and the other an inflammable. All the elements are considered as metals, except those marked with an asterisk. Many are of opinion that silicum ought to be classed with the non-metallic bodies.

60. The names of elements and other chemical terms are generally derived from Greek or Latin words expressive of some leading character of the substance indicated. In some cases they have been used from the most remote antiquity, or have been applied from circumstances altogether accidental.

61. In the systematic nomenclature of modern Chemistry, however defective it still may be, from the difficulty of changing names that have long been familiar, it is always considered desirable that the names of compounds should indicate their *composition*, the *proportion* of the respective *elements*, and their class or order; but in the great majority of cases, these objects are as yet only very imperfectly attained, as exemplified in the terms in daily use.

62. When the same elements, united in the same proportions, but in different modes, produce different compounds, in the same manner as a builder can produce different structures with bricks of the same form, such compounds are termed *isomeric*, from Greek terms signifying the same parts.

63. *Proximate principle* is a term applied to a compound, such as forms a part of a still more complicated compound.

64. Binary, ternary, quaternary compounds, &c., indicate the number of elements or proximate principles in a compound.

65. The names of binary compounds of oxygen, chlorine, iodine, bromine, and fluorine, when not acid, terminate in *ide*, as oxide of lead, chloride of mercury.

66. In binary compounds of other bodies, not acid, the name terminates in *uret*, as sulphuret of iron, hydruret of carbon.

67. The number of equivalents in the first element or proxi-

mate principle named in a compound, is indicated by a Latin numeral; as *bis*, *ter*, *quater* (or *quadro*), in binoxide of mercury, terchloride of gold, quadroxide of chlorine.

68. Greek numerals, *dis*, *tris*, *tetrakis*, indicate the number of equivalents in the second element or proximate principle, as in dinoxide of lead.

69. *Acids* form a numerous class of compounds, which usually have a sour taste, redden the vegetable blues, and lose their characteristic properties when they combine with alkalies, earths, and other substances.

70. *Oxacids* consist of oxygen and other elements.

71. *Hydracids* consist of hydrogen and other elements.

72. A termination in *ic* indicates an acid with much oxygen, as sulphuric acid; a termination in *ous* indicates an acid with less, as sulphurous acid.

73. *Aqueous* is a term now coming into very general use, instead of *hydrate*, to express the presence of water.

74. The term *salt* is applied to numerous compounds, consisting of acids and oxides, and has been lately extended to many varieties of compounds differently constituted, and containing neither acids nor oxides. A *salifiable base* is a term applied to alkalies, earths, metallic oxides, and various substances which can form salts by combining with acids and other bodies.

75. The names of salts are composed of the names of their component parts.

76. *ate* is the terminating syllable given in such cases to the name of an acid ending in ic, as in sulphate of potassa, composed of sulphuric acid and potassa.

77. *ite* is the terminating syllable when the name of the acid ends in ous, as in sulphite of potassa, which consists of sulphurous acid and potassa.

78. A *supersalt* indicates that the properties of the acid predominate, without reference to its composition, as in the supertartrate of potassa.

79. A *subsalt* indicates that the qualities of the base predominate, as in the sub-borate of soda.

80. A *neutral salt* expresses that the compound has none of the characteristic properties either of the acid or base, as in the sulphate of potassa: the term neutral is often omitted.

81. *Haloid salts* are compounds of chlorine, iodine, bromine, or fluorine, with metals.

82. *Oxysalts* consist of two compounds united together, in both of which oxygen forms a component part.

83. *Sulphosalts* are similarly constituted, the oxygen being in them replaced by sulphur.

84. All who wish to become familiar with chemistry ought to study the symbols of the most important elements. The manner of writing symbols is easily understood after a little practice; and if they be frequently used, they will facilitate as much the explanation of chemical action as the use of figures has simplified the operations of arithmetic. The following rules are to be carefully observed :—

85. The sign = is used to signify that the substances placed before it can produce, or can be resolved into, those placed after it.

86. Each dot prefixed to a symbol indicates 1 equivalent of oxygen. A dot is frequently used instead of O for oxygen.

87. Compounds are represented by the symbols of their elements. SFe = Sulphuret of Iron, is composed of sulphur and iron.

88. A figure prefixed to any symbol or symbols multiplies all that follow, unless a new sign intervene; thus, $2{\cdot}H{:}S = 2{\cdot}H+2{:}S$. A small figure placed after any symbol indicates that it alone is to be multiplied; it does not refer to any other symbol, thus: $H^2C = 2H+C$.

89. Brackets are often used in representing complicated combinations; for example, $[2HC^2N+C^2NFe]+2{\cdot}K$ = Ferrocyanic Acid + 2 potassa. A figure prefixed to any symbols placed between brackets multiplies them all, whether signs intervene or not: $2[2{:}S+{\cdot}K] = 4{:}S+2{\cdot}K$.

90. In the symbolic and diagrammatic illustrations & is used to signify a substance added to another, but + is placed between substances already in combination. Thus, $:S\&{\cdot}K$ signifies that sulphuric acid is to be added to potassa; but $:S+{\cdot}K$ means sulphate of potassa, or sulphuric acid already combined with potassa.

91. Many vegetable acids are represented most conveniently by italic capitals, adding some succeeding letter where more than one have the same initial letter :

A. Acetic,	*Ct*. Citric,	*P*. Prussic,
B. Benzoic,	*G*. Gallic,	*T*. Tartaric.

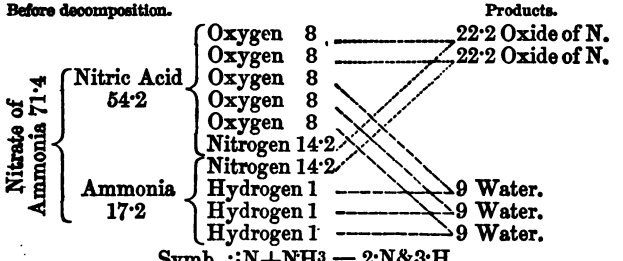
92. All cases of chemical action represented symbolically should be extended on a slip of paper (or on a diagram board by the teacher) in the following manner, so as to enable the student to become familiar with the changes which take place. This mode of illustration has been proposed as being better suited to the present state of the science than the diagrams formerly used.

93. To the left place the names or symbols of the substances employed. Arrange, in the next place, the names of the component parts under each other, or of the different matters that

are separated as the action proceeds. Lines traced from these, and uniting in a point, indicate those materials which combine. The lines are dotted when the products are gaseous, composed of smaller lines where they are liquid, and plain where they indicate the production or separation of any solid substance.

94. For example, the nitrate of ammonia is a compound of nitric acid and ammonia. Nitric acid contains five particles of oxygen and one of nitrogen, and ammonia consists of one particle of nitrogen and three of hydrogen. The weight of a particle of oxygen is 8, of nitrogen 14·2, that of hydrogen being 1. But when nitrate of ammonia is subjected to heat, all these particles take a new arrangement; two particles of oxygen with the two of nitrogen produce two particles of oxide of nitrogen, the three remaining particles taking the three of hydrogen. All these circumstances are rendered more distinct by the diagram, the nitric acid and ammonia being represented towards the extreme left; then the number of particles in each compound and their relative weights. The lines proceeding from these indicate the new arrangement, those that coalesce pointing out the new products that are formed.

Decomposition of Nitrate of Ammonia.—Fig. 1.



Symb. ::N+NH³ = 2·N&3·H.

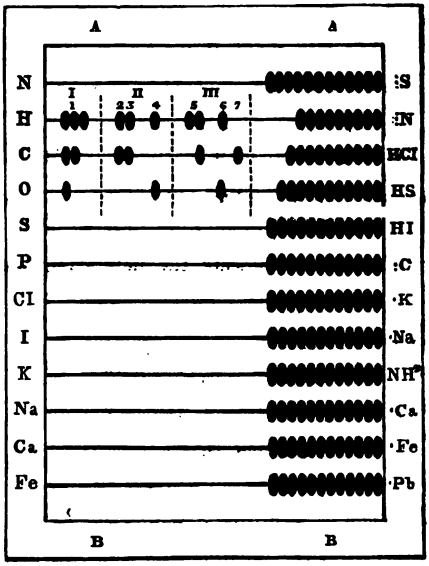
95. In studying the composition of compounds, the chemical abacus will be found very useful.

96. It consists merely of the common abacus so much employed by the ancients, and still used in different foreign cities, symbols representing elementary or compound bodies being placed along the side, as shown in fig. 2.

97. When the abacus is used, the beads are placed to the right, if intended to represent elements, and to the left when they represent compounds. The figure shows it arranged in the former manner, and six beads separated from the rest to illustrate the composition of alcohol. In I. they are all supposed to be united together; II. represents the same beads

disposed so as to represent the formation of two particles of hydruret of carbon (2 and 3) and one of water (4); III. shows another arrangement of the same elements, namely, bihydruret of carbon (5), water (6), and carbon (7). The student may procure a chemical abacus for sixpence or a shilling, or he may

Fig. 2.



make one for himself by stringing a few glass beads upon wire fixed in a wooden frame; he should practise frequently with it, till he becomes familiar with the various changes of which the most important compounds are susceptible, whether decomposed with or without the addition of other substances.*

98. In examining the composition and properties of many compounds containing gases, it is necessary to become acquainted with the bulk which their elements occupy as well as their weight. The following table should be frequently

* The use of the abacus for the above purpose, was suggested on observing the *facility with which* many calculations were made with it in places where it is *in daily use, and from* the conviction that it will contribute greatly to facilitate *the acquisition of a* more precise knowledge of chemical changes.

referred to, as it shows the composition by weight and by measure of the most important gaseous compounds.

The first column contains the names of different elements and compounds.

The second column contains the bulk or measure of the weight referred to in the succeeding column, hydrogen being taken as a standard of comparison. The square figure represents a whole measure, and the others indicate proportional quantities. Thus, in reading the sixth line, we say, Water in the gaseous state (steam) is represented by one measure, its equivalent weight is 9, and its symbol is OH.

The third column contains the weight of an equivalent quantity of each substance represented.

The fourth column contains the symbols of the elements and compounds represented in the preceding columns.

Gases and Vapours.	Equivalents by bulk.	Equivalents by weight.	Symbol.
Oxygen (half a measure),	▭	8	O
Sulphur (a third of a measure),	$\frac{1}{3}$	16·1	S
Phosphorus (half a measure),	▭	15·7	P
Hydruret of Carbon (half a measure),	▭	7	HC
Hydrogen (a whole measure),	□	1	H
Water,	□	9	OH
Nitrogen,	□	14·2	N
Oxide of Nitrogen,	□	22·2	ON
Carbon (hypothetical),	□	6·12	C
Carbonic Oxide,	□	14·12	OC
Carbonic Acid,	□	22·12	O^2C
Bihydruret of Carbon,	□	8·12	H^2C
Cyanogen,	□	26·44	C^2N
Sulphurous Acid,	□	32·1	O^2S
Sulphuric Acid (anhydrous),	□	40·1	O^3S
Hydrosulphuric Acid,	□	17·1	HS
Chlorine,	□	35·5	Cl
Iodine,	□	126·5	I
Bromine,	□	78·4	Br
Binoxide of Nitrogen (2 measures),	▭▭	30·2	O^2N
Ammonia,	▭▭	17·2	H^3N
Hydrocyanic Acid,	▭▭	27·44	HC^2N
Hydrochloric Acid,	▭▭	36·5	HCl
Hydriodic Acid,	▭▭	127·5	HI
Hydrobromic Acid,	▭▭	79·4	HBr

CHAPTER IV.

CRYSTALLISATION.

99. In many chemical operations, bodies are often procured in regular symmetrical forms, termed *crystals;* and the process by which they are formed is called *crystallisation.* Crystals are generally procured in one of the following modes :—

I. By melting solids, or converting them into vapour by the application of heat, allowing them to return slowly to the solid form.

II. By slow deposition from fluids in which they have been dissolved.

100. Before crystallisation can take place, the particles of the matter to be crystallised must have free liberty of motion, and the attraction that formerly bound them in a solid mass being now permitted slowly to resume its force, they gradually attract each other by those extremities, sides, or angles, which determine the production of regular figures, according to the relations or tendencies with which they have been created by the Author of Nature. Heat, or the action of a solvent, is required in the first instance to give that freedom of motion which is essential to crystallisation ; and when their influence is slowly withdrawn, the particles have time and opportunity to assume that position which develops crystals.

101. If the action of the heat, or of the solvent, be suspended suddenly, the particles resume the solid form indiscriminately ; and however regular the form of each may be, still, from the want of a regularity in their aggregation, nothing but an amorphous mass is observed.

102. The first portion that becomes solid in the process of crystallisation, draws other particles successively to it ; these do not fall indiscriminately upon each other, but attach themselves by one part rather than by another to those already deposited, according to properties communicated to them when they were originally formed. The extremities of the particles are considered to draw to each other exactly in the same way as a suspended magnetic needle points to the north and south, while it refuses to turn in any other direction.

103. Of late years, numerous cases have been pointed out where the form of solids has been changed, without inducing fluidity previously either by heat or other means. If the yellow binoxide of mercury be touched by any hard substance,

a creeping motion is observed among its particles; they assume a new arrangement, and the colour is changed to bright scarlet. In sulphur and many salts at ordinary temperatures, and in iron and other substances at a high temperature, similar changes have been observed; and even in masses of particles merely mechanically mixed with each other in the first instance, a crystalline arrangement is often subsequently developed.

104. In such cases, crystallisation may sometimes be attributed to the alternate action of various temperatures, such as occur in the atmosphere at the surface of the earth; and these, by favouring expansions and contractions, give the particles in the small contiguous masses an imperfect opportunity of cohering together. In other cases, moisture, or an electrical action, has been supposed to induce the change that takes place.

105. The minute particles, or atoms of matter, are all considered to have fixed and definite forms, so that, were a sufficiently powerful magnifying glass constructed, it is considered that these would be distinctly seen, whatever might be the nature of the substance examined. In all crystals a nucleus is observed, which is often very different from the external form of the crystal. It is obvious that crystals of the same kind of matter may be obtained in a great variety of forms, according to the manner in which the particles are disposed upon each other, in the same manner as a builder can produce a vast variety of architectural figures with bricks of the same size and shape, according to the manner in which he arranges them. Several hundred varieties of crystals of carbonate of lime have been pointed out; but if any of these be broken with a gentle blow, so that the different laminæ may separate, innumerable fragments of a rhomboidal form are obtained, and no other shape is presented.

106. A number of groups of different substances have been pointed out, the forms of whose particles are considered to be similar. They are said to be *isomorphous*, and when they combine with different portions of the same body, the forms of the crystals of the new compounds are also isomorphous.

107. Crystallisation is observed in all the products of the mineral kingdom, where they have not been ground down by a rude mechanical force, or separated in the first instance in particles too minute to admit of their form being recognised.

108. Melt 2000 grains of sulphur by applying heat cautiously. After placing it in a flask, then remove the heat, pour out half of the liquid when the other half has consolidated, and observe the crystals of sulphur.

109. Put alum into 8 or 10 ounces of water at a boiling heat,

in a glass or earthen vessel, adding it so long as it is dissolved. Allow the liquid to cool; crystals are deposited. Hot liquids dissolve more of most substances than those that are cold, and if charged when warm with as much of any of them as they can dissolve, part is deposited on cooling.

110. Expose a solution of oxalic acid or glauber salt to the air for some days on a shallow plate; the water is in part slowly removed, and crystals appear. By reducing these substances to powder, and shaking them with water so long as any is dissolved, a solution is very quickly procured.

111. The state of the air on some occasions has a great influence on the crystallisation of salts from watery solutions. So well is this known to the manufacturer, that the same language is in familiar use in many crystallising establishments as is adopted by the farmer; the workmen sometimes looking forward to the condition of the atmosphere—particularly where many salts are in the same solution, one of which is expected to crystallise before the others—with the same anxiety, and talking of the crops of epsom or of glauber salts much in the same way that the farmer speaks of his crops.

112. The influence of the air on crystallisation is beautifully shown by heating glauber salt in a flask half full of boiling water till no more is dissolved, corking the flask when the air has been expelled by the steam on boiling the solution, and then removing it from the heat. The solution does not crystallise on cooling; but if the cork be now removed, the crystallisation commences as the air enters, extending rapidly till a solid crystalline mass is formed. The air operates principally by abstracting some of the water of the solution, and causing the precipitation of a minute crystal, from which the crystallisation proceeds till it ramifies through the whole mass. When the weather is warm, and the crystallisation does not ensue quickly on taking out the cork, the introduction of a small crystal usually determines it immediately.

113. Heat a tinned iron-plate before the fire, or over a lamp, till it is as warm as may be necessary to cause water dropped upon it to evaporate quickly with a slight hissing noise. Let the tin with which the iron is coated be then washed with a cloth well moistened with a mixture composed of water 1 ounce, muriatic acid 1 drachm, and nitric acid 1 drachm. The cold fluid causes the hot tin suddenly to assume a crystalline form, and as the acids act upon the external particles of the tin, and expose those below, the crystalline arrangement is beautifully seen. When varnished, it retains its lustre; the varnish may be coloured of any tint that may be required.

114. Crystals and other solid substances which attract mois-

ture from the air and become fluid, are said to *deliquesce;* those that lose moisture under the same circumstances, and assume the appearance of a powder, are said to *effloresce.*

CHAPTER V.

HEAT OR CALORIC.

115. Chemical action being affected powerfully by heat, light, and electricity, it is necessary to attend to their influence before entering upon the history of individual substances. All the effects commonly attributed to heat, are produced by its entering and attaching itself to the substance affected, while those which are said to be caused by cold, arise in reality from a portion of heat leaving those substances with which it has been associated. In common language, the term heat is employed in two ways, indicating either the sensation of warmth, or the cause of that sensation and of such other effects as are attributed to it. The term *caloric* was introduced to signify the matter or power of heat alone.

116. No agent is more universal in its influence on matter than caloric. There is nothing in this globe that we can see or touch that does not contain it. Were caloric withdrawn entirely from matter, it is impossible to conjecture what appearance it would present, but even with a more moderate reduction in its amount, the whole ocean would be changed into ice, and universal death would ensue both in the animal and vegetable kingdoms. On the other hand, were its intensity greatly increased, destruction would equally attend animal and vegetable life, the whole ocean might be dissipated in vapour, and even the solid matters that compose the earth might be volatilised by its powerful agency. There is nothing, however, whose precise relation to the minute particles or atoms that compose masses of matter is more imperfectly understood; and whether it pass from the sun to the earth, from the open fire to the human frame, from the furnace of intense heat to the materials used in the operations of art, or be developed in a more subtle form by the various changes in matter that accompany a living action in the bodies of animals or in plants, still no clue has been obtained as to the manner in which it is associated with their minute particles.

117. Caloric not only induces a vast variety of modifications in the properties of individual substances, according to the pro-

portions in which it is communicated to them, but is also distinguished by certain general effects which it produces, more especially *expansion*, *liquefaction*, *vaporisation*, *evaporation*, and *incandescence*.

118. No one has been able to collect heat and show it by itself; it is invisible, has no appreciable weight, and sooner or later it can penetrate every thing with which it may be surrounded. It is known only by its effects, and is considered a peculiar fluid, easily thrown into vibratory movements.

119. Heat tends always to pass from the hotter to the colder substance, till both bodies acquire the same condition in this respect, when they are said to attain an *equilibrium* of temperature.

120. The *temperature* of any substance indicates its disposition to communicate heat to, or remove it from, any standard of comparison; if the temperature of the body be taken as a standard of comparison, those substances at a higher temperature communicate heat to it, while those at a lower temperature remove heat from it.

EFFECTS OF HEAT.

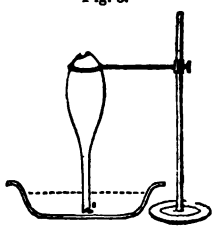
121. EXPANSION.—Bodies, with few exceptions, are expanded by heat; gases expand most, liquids come next, and solids last of all. When heated from 32° to 212°, air expands 3-8ths of its volume, alcohol 1-9th, water 1-22d, and hammered iron 1-273d.

122. Measure the length of a cold iron rod or bar; heat it to redness, and it will be found longer.

123. Fill a long narrow-necked flask nearly full of alcohol, and put it into boiling water; the alcohol as it expands rises in the neck of the flask.

124. Pour boiling water upon the same flask full of air, after inverting it in water (it may be supported or steadied in this position by a ring of the retort stand); part of the expanded air is expelled; and water is forced back by the pressure of the air to supply its place, when it again becomes cold.

Fig. 3.



125. EXCEPTIONS.—Water contracts as it is heated from 32° to 39½°. Many solids contract as they are melted by heat, expanding again as they become solid—as ice, iron, antimony, bismuth, and many salts.

126. The communication of heat causes expansion to take place with great force; iron-bars, for instance, often cause rents in furnaces as they expand. A tough solid, such as iron, con-

tracts with great force on cooling. Water, and other melted solids, expand with great power as they become solid, bursting the vessels containing them when they are not allowed to escape in part by any aperture. A phial full of water, and corked tightly, bursts as it is frozen.

127. The common "*thermometer*" contains a fluid which indicates the communication of heat, by expanding and rising in the stem, and the removal of heat (cold) by contracting and descending. Thermometers are graduated, and made to correspond with each other by observing the different points to which the fluid rises in freezing water and in boiling water; the space between these is in this country usually divided into 180 parts, 32 being placed opposite the point where the water freezes, and 212 opposite the point where the fluid stands when the water boils. Similar spaces are marked off upon the stem above and below these points, and numbered accordingly. It was at one time imagined that the greatest cold could make the fluid fall only 32 such spaces below the freezing-point, the place to which it then fell being termed *zero*, and the notation commencing there. But much greater degrees of cold exist at different parts of the globe in winter, and may be produced artificially, so that the fluid in the stem of the thermometer often descends below that point, and is then said to be at so many degrees below zero. Thus, 52 degrees below the freezing-point, or 20 degrees below zero, is usually written — 20°.

Fig. 4.

128. LIQUEFACTION.—Heat is considered to be the cause of liquefaction, melting all solids which it does not previously decompose. When any solid melts, much heat is required to effect this change in its form after it arrives at the melting-point. Pour some boiling water upon ice at 32 degrees; the ice melts rapidly, but the water produced is no warmer than the ice; the heat is consumed in melting the ice, and is said to become *latent*, as it does not affect the thermometer. Pour boiling water upon ice-cold water, and the temperature is immediately increased.

129. When a fluid becomes solid, it gives out without cooling the heat which had rendered it fluid; the change proceeds slowly, as so large a quantity of heat must be withdrawn. As much heat is required to melt ice as would raise the temperature of an equal weight of ice-cold water by 140 degrees; it melts, *accordingly* with extreme slowness. Were no heat to

become latent as snow and ice melt, they would liquefy with great rapidity, and produce inundations that would in many places be altogether destructive of animal and vegetable life.

CHAPTER VI.

VAPORISATION.—SPONTANEOUS EVAPORATION, &c.

130. The term *vapour* is applied chemically to all thin, attenuated, and gaseous substances, such as can be formed by the action of heat on solids and liquids, and can be restored again to the liquid or solid form by withdrawing the heat communicated to them.

131. *Gas* is a term applied to matters such as air, equally thin and attenuated as vapours, but not met with in a condensed form under ordinary circumstances, and not capable of being reduced to the liquid or solid form, except by such intense cold or extreme pressure, that only part of them have as yet been brought to these conditions. They are considered as vapours requiring a temperature for condensation so low that many have never yet been seen in the liquid form. The air we breathe is thus considered to bear the same relation to a peculiar liquid and solid not yet discovered, that steam does to water and ice. It is the steam of a solid that no one has yet seen, but which even at ordinary temperatures is far beyond the point at which, were it previously liquefied, it would boil and disappear in vapour. Sulphurous acid gas may be liquefied by a very moderate cold, namely, 14 degrees of Fahrenheit. The most interesting experiments on the liquefaction of gases have been made with the carbonic acid gas. When large quantities of the liquefied gas are allowed to escape from an appropriate apparatus, intense cold is produced, and one portion is frozen by the cold developed as the other evaporates. The frozen carbonic acid is a white solid as light as snow. Though reduced to a temperature of — 180°, it may be put into the mouth without injury, producing a very peculiar sensation, as it has the sharpness of ginger-beer, without moisture or any peculiar flavour, feels perfectly dry, and passes at once from the solid to the gaseous form. Were it capable of abstracting heat more perfectly, as mercury or other metals, it could not be brought near the skin or mouth without injury.

132. There are a number of gases, all differing more or less from each other, in the same manner as different solids or

liquids; and, according to the opinion now universally entertained, they may be regarded as solids which have been melted, evaporated, and heated beyond their boiling-point.

133. The temperature at which different liquids boil is very various, as well as the density of the vapour, and the amount of heat required to produce it; water, however, may be taken as an example to illustrate the general nature of the process of vaporisation.

134. *Vaporisation* signifies the rapid production of a thin vapour, as when water is boiled and produces steam.

135. Water boils at 212 degrees, and does not become warmer as it boils, the heat applied being consumed in producing a change of form. Hence, it is not economical to boil any substance quickly which may only require exposure to a boiling temperature, as all the heat that may be consumed in producing the vapour must cause an unnecessary expenditure of fuel.

136. Put a thermometer into water, mark where the fluid stands in the stem as the water boils, and observe that it rises no higher, however long the boiling may be continued.

137. As much heat is required to produce steam from boiling water, as would elevate the temperature of an equal weight of boiling water by 1000 degrees,* were it still to remain fluid. Steam, though it contains so much heat, is always at the same temperature as the water from which it rises, the caloric that produces it being engaged as it were in sustaining the change of form induced in the water, without being able to produce any increase in the temperature. The heat that produces the steam is said to become latent as in the liquefaction of solids.

138. Steam is transparent, colourless, and invisible, like the air. The white cloudy-looking matter usually called steam, is moisture produced by the condensation of steam. Steam occupies 1696 times as much space as an equal weight of water, and as it expands with great force, it often bursts and destroys vessels in which it is confined. When the power with which it expands is carefully regulated, so as to produce motion in machinery, it forms the most powerful engine man has invented, namely, the steam-engine.

139. When steam is exposed to cold, it condenses into water, giving out all the heat by which it was produced; and hence the large amount of heat it may be made to convey, and the severe burn it produces when condensed on any part of the body.

140. Boil a small quantity of water in the flask represented

* Different estimates have been given of the precise amount of heat that becomes latent during vaporisation, some exceeding and others being less than the amount stated.

in fig. 3; put in a cork when the air is expelled, and open the flask cautiously under water; the steam, which previously nearly filled the flask, being suddenly condensed, the pressure of the air forces up water to supply its place.

141. Water boils at a lower temperature than 212 degrees, when the air is not allowed to press upon it; fill the flask already alluded to (fig. 3) one-half full of water, boil it briskly, and cork it while the steam is escaping, removing the heat immediately. The cold air condenses the steam, the cork prevents the air from entering, and the water thus relieved from pressure begins to boil, the heat already in it being sufficient for that purpose. Put the flask into cold water; the ebullition then increases, the steam being still more effectually condensed. Put the flask into boiling water, the steam being no longer condensed presses upon the water, and prevents it from boiling.

142. If steam be not allowed to escape, and heat be continually applied by the fire, a higher and higher temperature is required to make the water boil, and the steam formed acquires more and more power, each successive portion compressing much of what had been already formed. It is then called *high-pressure steam*, as it presses upon the sides of the boiler with great force. Boilers in which such steam is produced ought always to be provided with valves which the steam can push open, and by which it may escape before it becomes strong enough to burst the boiler.

143. It is a curious circumstance that steam always contains the same amount of heat, whatever be the temperature at which it is formed; the latent heat required for its production being less and less as the temperature at which it is formed is increased by preventing its escape.

144. The greater the pressure to which water or any other liquid may be exposed, the more elevated is the temperature required to produce vapour, the more dense is the vapour formed, and the greater is its explosive or moving power.

145. Fig. 5 is a section of part of a boiler where the safety-valve is placed, the valve being loaded with a weight which the steam can raise before it acquires strength to burst the boiler. In examining the construction of boilers, the different parts noted in fig. 6 should be attended to: *a*, *b*, the body of the boiler, filled with water and steam; *c*, a pipe by which water is forced into the boiler; *d*, the steam-pipe; *e*, a glass tube or gauge placed so that the steam and water can enter freely into it, the water being always at the same height in it as in the interior of the boiler; *f*, *g*, two pipes placed so that the quantity of water in the boiler may be ascertained, when the glass tube is not used; if water come from both, on open-

ing the stopcocks, and when there is abundance of steam in the interior of the boiler, there is too much water, and if steam be disengaged from both, then there is too little; the boiler

Fig. 5.

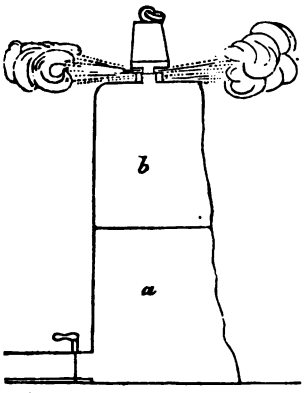
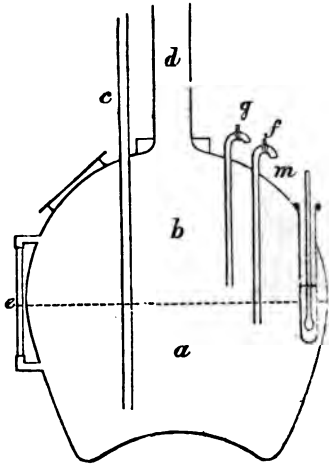


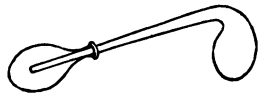
Fig. 6.



should be charged so that one gives steam and the other water, the level of the water in the boiler being between the extremities of the tubes within the boiler; *m*, a thermometer, indicates the temperature in an iron tube containing mercury.

146. Distillation consists in the production of vapour by heat, which is afterwards condensed. The vessel in which the vapour is produced is called a *retort;* that in which the condensed vapour is collected must be kept cold, surrounding it with a cloth, and moistening it with water; it is termed a *receiver*. Fig. 7 represents a retort and a receiver.

Fig. 7.

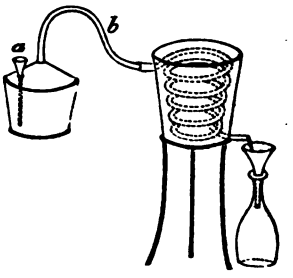


147. When a large quantity of fluid is to be distilled, it is introduced into a vessel called a *still* (fig. 8), the pipe from it leading to a vessel termed the *refrigeratory*, as it is filled with cold water; the vapour is condensed in the coiled pipe, or *worm*, as it is often called, and escapes through it into a receiver placed below it.

148 *Spontaneous evaporation* is the term usually employed

when vapour is produced slowly from a fluid, and without ebullition, as when water disappears from any moist surface. Water evaporates in large quantity from the surface of the ocean, and from the earth also, eventually producing the clouds, or condensing in the form of rain and dew. Snow is formed when the vapour is frozen at once, and hail when rain is first produced, and then congealed by the cold.

Fig. 8.



149. Evaporation is always accompanied by the production of cold, when no heat is directly applied; the heat necessary for the production of the vapour is then derived from surrounding objects, and from part of the liquor evaporated.

150. Pour some ether, or any other volatile fluid, on the back of the hand; great cold is perceived as it evaporates. If we blow upon it, the vapour resting on the surface is rapidly removed, evaporation proceeds more quickly, and a more intense degree of cold is produced.

151. Evaporation proceeds more and more quickly the higher the temperature; the greater the extent over which the evaporating fluid is spread, the less the pressure of the air, and the nearer the evaporating substance approaches the boiling point. At the summit of high mountains, where the pressure of the air is less than at the surface of the earth, water boils at a lower temperature than 212 degrees; it is there above a large portion of the air which presses upon the surface of less elevated regions.

152. A current of air, when not loaded with moisture, promotes evaporation; hence the rapidity with which a wet surface generally dries on a windy day, the vapour resting upon it being pushed away, and a new portion rapidly formed.

153. Moisture is separated from the air in which it is diffused, by a reduction of temperature. Sometimes it forms innumerable small vesicles; the mode of their production is not known. When they are associated together in large quantities, they produce clouds. The water evaporated from the surface of the ocean, &c., being purified from the materials with which it may have been mixed at the surface of the earth, and falling down afterwards in the form of rain, hail, snow, dew, or hoar-frost, becomes fitted for the various purposes for which it is so necessary in the animal and vegetable kingdoms.

154. Instruments for determining the amount of moisture in the air have been invented; they are usually termed hygrometers.

155. The nearer the equator, the greater the annual fall of rain, and the less the number of rainy days. At Granada, 12 north lat., the rain which falls annually would cover the surface to the depth of 126 inches, were it all to be deposited at the same time. In this country, it is calculated that the annual fall of rain would, on an average, cover the surface to the depth of 32 inches.

EXOSMIC AND ENDOSMIC MOVEMENTS.—DIFFUSION OF GASES.

156. All bodies brought into close contact generally produce
A mechanical intermixture,
A mechanical adhesion, or
A chemical union.

157. One of the most important kinds of intermixture hitherto noticed, is that which takes places in fluids of different qualities approximated to each other so as to come into actual contact when they begin to act, if they have any chemical attraction for each other, even if membrane or any porous substance be interposed, provided it be moistened with one of them. A variety of circumstances determine the currents, more particularly the permeability of the interposed fibre, membrane, or porous cup, the movement taking place most largely from the liquid to which the porous structure is most permeable.

158. The movement produced in this manner appears to depend principally upon the attraction exerted between the particles of the different fluids employed, as they meet in the porous membrane. When the movement proceeds from the interior of any cavity, it is termed *exosmosis*. But the movement of the other fluid inwards is termed *endosmosis*; a portion of one always enters as a part of the other presses outwards.

159. The *diffusion of gases* is an action similar in some respects, but very different in others. It consists in the gradual intermixture of gases, in a proportion bearing a relation to their specific gravity, when they are placed in communication with each other. This operation, as in the case of fluids, often takes place with great force, the vessels bursting where the action advances most rapidly; they are made of bladder or similar materials. Diffusion takes place not only through porous and membranous solids, but may be often observed in situations where water is completely retained, as through a cracked glass, or through a tube of glass having the extremity

filled with plaster of Paris, air passing freely through these in many cases when water cannot pass.

160. To illustrate the diffusion of gases, procure a glass tube 12 or 18 inches long, and half an inch or an inch in diameter. Obstruct one end with a plug of plaster of Paris about half an inch thick; fill it with hydrogen gas by means of a long narrow tube, through which the hydrogen is introduced from a bag or gasometer, holding the tube perpendicularly with the plugged extremity uppermost. On withdrawing the internal tube, and placing the open extremity of the other under water, the hydrogen begins to escape so quickly by diffusion from the plugged extremity of the tube through the plaster of Paris, that the pressure of the atmosphere forces the water up to the height of several inches to supply its place; after a time, however, a proportionate quantity of air enters, and the water regains its original level.

161. The diffusion of gases may also be illustrated in a very simple manner, by taking a bottle filled previously with hydrogen gas, and another with carbonic acid gas, connecting them together, as represented in the figure, and inverting the bottle with the hydrogen over the other containing the carbonic acid. Notwithstanding the lightness of hydrogen, and the heaviness of carbonic acid gas, still, from the operation of the diffusive power which has been described, part of the light hydrogen descends into the lower bottle containing the carbonic acid, while, at the same time, a corresponding portion of heavy carbonic acid ascends and mixes with the hydrogen in the upper bottle.

Fig. 9.

162. INCANDESCENCE.—All solids and fluids which are not converted into vapour at a less elevated temperature, become luminous when heated to 800 degrees in the dark, or when heated to about 1000 degrees in daylight. A red light appears at first, and gradually passes to a white as the temperature increases. This is observed equally in combustible solids, as charcoal, and in stony or other matters which do not burn; they are then said to be in a state of *ignition* when they are red hot, and *incandescent* when they are at a white heat.

CHAPTER VII.

COMMUNICATION OF HEAT.

163. Caloric is communicated by *conduction* and *radiation.*

164. When caloric passes slowly from one portion of matter to another in contact with it, it is said to be *conducted,* and the process is termed the *conduction of caloric.* Metals are the best conductors, then liquids, and lastly gases. Gold, silver, and copper, are the best conductors among solids; glass, bricks, and many stony substances, are very bad conductors; and porous spongy solids, as charcoal, hair, and fur, are the worst.

165. Put one end of an iron rod in the fire; the heat soon passes to it, and along its particles to some distance from the fire. Put a glass tube, or piece of wood of the same size as the iron, into the same part of the fire; the heat extends a very little way beyond the part touching the fire, both these substances being bad conductors.

166. Many of the more familiar phenomena of nature and of art depend upon the conducting power of different bodies. Thus, iron and cotton, if cooled to the same temperature below that of the body, do not affect it equally when applied to it; the iron produces the strongest impression, as it conducts the heat most rapidly away. Again, if they be raised to a high temperature, the iron still produces the strongest sensation, communicating heat most rapidly. In short, the good conductor always produces the greatest effect, either by communicating heat more freely than the cotton or by removing it.

167. Clothing is generally made of bad conductors, that the heat of the body may not be conducted quickly to the surrounding air. Furnaces, where great heat is required, are built with porous bricks, which are very effectual in preventing the escape of heat; but when a stove is placed in the middle of any apartment, the fuel is surrounded with iron, that the heat may be quickly conducted to the air. The ice in an ice-house is surrounded with bad conductors, to prevent warm air coming in contact with it, or transmitting heat to it.

168. When heat is applied to the upper portion of any liquid, expansion generally ensues, and it becomes lighter than the rest; it remains, therefore, resting upon the colder and heavier part. This may be easily shown by boiling the upper portion of water in a long glass tube, applying heat by a spirit-lamp. If the heat be applied near the bottom of the tube, fig. 10, the colder portion from above soon sinks below the hot expanded fluid, and pushes it up, so that currents are continually pro-

duced, till the whole fluid is heated to the same point. If the water at the bottom of each tube be coloured, that in fig. 10 is

Fig. 10.

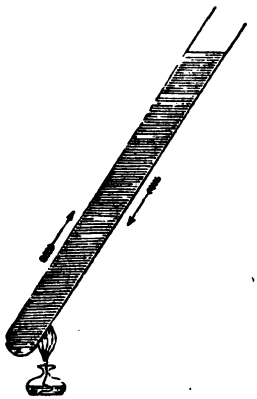
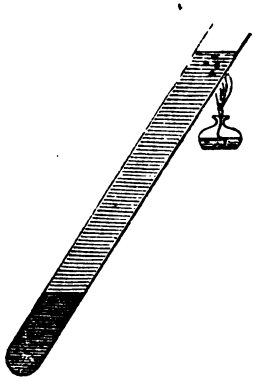


Fig. 11.



soon seen to mingle with the water above it, but the coloured water in the other does not move.

Fig. 13.

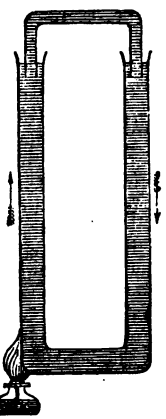


Fig. 12.

169. If heat be applied to a glass vessel containing water, as

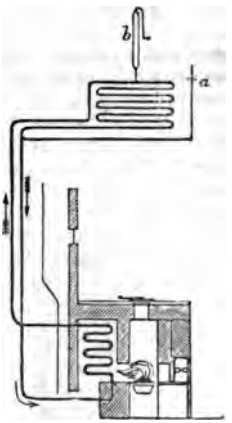
represented in fig. 12, the water in contact with the warm glass expands, the colder water in the centre descending and pushing up the warm water at the sides.

170. If water be placed in a glass tube bent in the manner represented in fig. 13, and the water at the extremities be connected by another smaller and similar tube, then, on applying heat to the lower part of one of the limbs, the water begins to move in the manner shown by the arrows. The colder and comparatively denser and unexpanded water in the one limb, descends and pushes up the warmer water in the other limb, assuming the place of the hot water. Subsequently, it becomes heated in its turn, and thus the circulation is continued so long as any inequality of temperature is sustained.

171. On the same principle, boilers are now constructed which convey heat from the fire to which they are exposed through tubes or iron cases to the air of different apartments, diffusing a gentle and equal warmth or a sharper heat, according to their structure and the amount of heat to which they are subjected.

172. Such apparatus may be obtained of two kinds; the first, according to Mr Price's patent, never heats the air in contact with it above 212 degrees. In the other, introduced by Mr Perkins, the water can be heated to a much higher temperature, in cases where this may be considered desirable. The annexed figure illustrates the general arrangements adopted according to his system. It consists merely of a series of coils of tube, part of which are placed where the water is to receive heat, and the rest where the heat is to be evolved. *a* represents a pipe for introducing water, and *b* an expanded portion of tube, intended to contain any excess of water when expanded by the heat.

Fig. 14.



173. Similar movements take place in the air.—See the section upon Carbon, where illustrations are given of the currents produced by a common fire.

174. Caloric is said to be *radiated* when it passes with great velocity from the sun, or from any warm body at the surface of the earth, moving through space, or through the air. It is believed in this case to move with the same velocity as light, namely, 192,000 miles in a second. Caloric is also radiated

from warm bodies that are not luminous, as from the hand, or from hot water.

175. Radiant caloric is absorbed when it falls upon bodies having painted or rough surfaces, such as are presented by bricks and other porous solids, by many kinds of stony matter, and numerous animal and vegetable substances, and elevates their temperature as it is taken up. But brilliant and polished metallic surfaces absorb little heat; they reflect or turn it back again.

176. Take a piece of common tin-plate, and place it before the fire, it reflects most of the radiant heat, and becomes warmer with extreme slowness. Make the surface rough with a file or sand-paper, cover it with lamp-black, or black paint; it now absorbs heat quickly when exposed to the fire, and soon becomes warm.

177. Those bodies which are most powerful in receiving radiant heat when it falls upon them, are equally powerful in emitting it when they are warmer than surrounding objects. Thus, a vessel with hot water, having a rough, porous, or painted surface, cools much more quickly than when the surface is brilliantly metallic.

178. All bodies at the surface of the earth lose heat by radiation in a clear evening; they radiate more or less heat according to the nature of the surface; those that radiate most become colder than the others, and on these more dew or hoar-frost is deposited, the air coming in contact with them being cooled to the greatest degree, and unable, therefore, to retain all the moisture previously associated with it. The green leaves of vegetables are powerful in radiating heat, and are accordingly covered with the dew during the night, which is so necessary for plants when there is no rain.

179. In a cloudy night, as heat does not escape by radiation from the surface of the earth, the temperature never falls so much as in a cloudless sky.

CHAPTER VIII.

DISTRIBUTION OF CALORIC.

180. Caloric is unequally distributed over the globe. At the equator the average temperature is 82½ degrees; at the poles it is believed to be about 13 degrees below zero. The higher we ascend in the air, the colder it becomes; the summits of very high mountains are always covered with snow. The

interior of the earth is generally believed to be at a very elevated temperature; many consider the numerous volcanoes that appear at its surface to arise from a central fire.

181. Caloric tending always to an equilibrium, the heat at the warmer portions of the surface of the globe is carried in part to those that are colder by currents in the air and in the ocean, so that the extreme severity, both of heat and cold, is thus mitigated.

182. The amount of caloric is not the same, even in equal weights of different bodies at the same temperature; as a wide jar requires more liquid to fill it to a certain height than is necessary to fill a narrow jar to the same height, so, many different bodies require more heat than others to elevate their temperature to a fixed point. Take a small jug of boiling water, and mix it with an equal bulk of cold water, previously placed in a flask or basin, and examine the temperature with a thermometer. Then mix equal bulks of boiling water and cold oil in another vessel, and the temperature of the mixture will be greater than before; the heat which the boiling water loses, elevating the temperature of the oil by a greater number of degrees than an equal bulk of cold water.

183. PRODUCTION OF HIGH TEMPERATURES.—Heat is developed principally by burning inflammable substances.—(See Air and Carbon). It may also be excited by mechanical action and by electricity. A most intense heat is produced when the rays of the sun are collected by a burning-glass, which bends the heat passing through it in such a manner that much of it falls upon one point.

184. Hammer a piece of iron on an anvil, it soon becomes very warm. Rub a thin piece of phosphorus, not greater than a quarter of a grain, with a piece of glass; after placing it in paper, it soon inflames when exposed to the air.

185. PRODUCTION OF LOW TEMPERATURES.—By placing volatile fluids where they evaporate rapidly, as in a current of air, considerable cold is produced. Pour any volatile fluid on the hand, and blow upon it; it evaporates with great rapidity, producing cold as the vapour formed removes heat from the hand. (See Vaporisation and Spontaneous Evaporation.)

186. Again, solids which are rendered fluid without the application of heat, become very cold. Mix two parts of snow or pounded ice with one of salt; the mixture soon becomes fluid, and the temperature falls 41 degrees below the freezing-point of water, if large quantities be used, and the snow and salt be in a minute state of division.

187. Mix 16 ounces of water with 5 of nitre and 5 of sal-ammoniac in fine powder: the temperature falls about 40

degrees as the salts dissolve in the water. Boil off the water, and collect the dry salts, which may be used again and again for the same purpose.

CHAPTER IX.

LIGHT.

188. Light is intimately associated with heat, and appears in all solids and liquids that are intensely heated. It can also be separated from the particles of numerous bodies when they enter into new combinations, or are liberated from those of which they may have previously formed a part.

189. Ordinary white light is considered capable of being divided into two parts or pencils, each composed of white light, and these, when separated, are said to constitute *polarised light*. The separation may be effected by certain minerals, or by allowing light to fall upon different substances at a particular angle, when one of these parts or pencils is transmitted, while the other is reflected.

190. Newton considered that white light consisted of seven different species of coloured light combined together, namely, red, orange, yellow, green, blue, indigo, and violet. It is the more general opinion now, however, that white light is composed of three varieties of coloured light, namely, red, yellow, and blue, as all other tints can be produced by them.

191. The influence of light upon chemical action is not so well understood as that of heat; nevertheless, there are numerous instances in which it produces a very marked and striking effect.

192. The *daguerreotype* affords perhaps the most interesting illustration that has yet been pointed out. There, plates of silver, acted on previously by the vapour of iodine, are placed so as to be exposed to the rays of light emanating from any object of which a sketch is desired. As these rays rest upon the iodine and silver, they so affect the chemical relation and position of the minute particles, that a new arrangement becomes visible after subjecting the plates to the vapour of mercury. The rays of light, therefore, may be said to have traced the outline of the image from which they came as they rested upon the plate. A solution of hyposulphite of soda is then poured over the plate, which precludes farther change.

193. Again, the action of light may be beautifully seen in experimenting with *photogenic* paper. This paper may be pre-

pared by moistening common writing paper with a very weak solution of nitrate of silver, or of bichromate of potassa, excluding it very carefully from the light except when it is in use. On exposing it to the sun, or to the bright light of day, the paper is darkened, and if any part shall have been covered by a leaf, a flower, or any other object, the portion of paper below it remains unchanged, presenting the outline required, while all other parts are darkened. By washing the paper subsequently with water, a solution of hyposulphite of soda, or some other chemical preparation, according to the nature of the material used, no farther change can ensue, and the sketch or outline is at length fixed on the paper.

194. The action of light is also conspicuous in its influence both on plants and animals. Exclusion from the rays of the sun leads to a pallid complexion, indicating a low state of vitality. In the vegetable kingdom, plants placed in a dark situation send out shoots to any opening where light can enter.

195. Clothing of different colours has long been noticed to attract odorous matters with different degrees of force. The darker the tint the greater the power of attraction, and the longer is the odorous matter retained.

196. On the human frame the precise nature of the action of light has hitherto engaged comparatively little attention; but its effects are admitted to be of great importance, however difficult it may be to trace its mode of operation; and if, in the daguerreotype, it is observed to affect so greatly the particles of dead matter taken from the mineral kingdom, it may be presumed to exert a still more important influence on the body, where the vitality of the materials renders them much more amenable to the influence of external agents.

CHAPTER X.

ELECTRICITY.

197. All bodies present a very peculiar series of properties when placed under particular circumstances, and these have generally been ascribed to the presence of a very subtle fluid, which has been termed *electricity* or the *electric fluid*. Various opinions are entertained as to the nature of this fluid, but nothing precise is known, except many of the effects it can produce on matter. Thunder and lightning are produced by the movements of electricity, such as may be experimented with on the small scale in using the common electrical machine.

198. Electricity, like heat, is in itself invisible, though often accompanied both by heat and light. It exists in all kinds of matter, and does not present, under ordinary circumstances, any manifest indications of its presence. But when any body acquires a larger proportional share than surrounding objects, whatever may be the cause, immediately electricity begins to pass from it to the others, this change going on till any excess is divided between them, and an equilibrium established. During this interchange, various phenomena may be observed, more particularly new powers of attraction or repulsion in the substances used, which at the moment are capable of attracting or repelling such matters as may be placed near them, if they are not too heavy. On the small scale, a spark is generally seen at the same time; on the large scale, in the phenomena of nature, the electric power either is or causes lightning as it passes from the clouds to the earth, from the earth to the clouds, or from one cloud to another. A very intimate connexion has also been discovered to subsist between electricity and magnetism; magnetism can indeed be produced in iron by electrical operations, and magnetic instruments are equally capable of producing an electric spark.

199. Bodies having more than their usual share of electricity, are said to be *positively electrified;* those that have less, are said to be *negatively electrified.*

200. *Electric conductors* are bodies through which electricity is conveyed with comparative facility and rapidity; among these, metallic substances are the most powerful, and through them, notwithstanding the solidity of their texture, it appears to move with the rapidity of lightning. Charcoal, acids, water containing salts in solution, and most animal substances, come next in order.

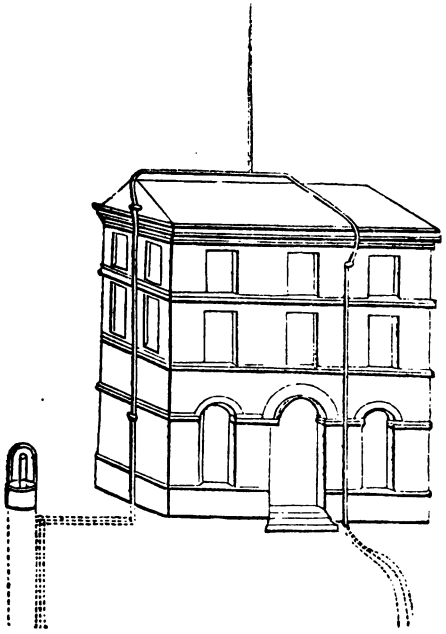
201. The *lightning-rod,* so much employed in defending buildings from the injurious effects of lightning, affords a good illustration of the application of conductors to practical purposes. The pointed extremity of the rod is freely exposed above the highest part of the building, as is seen in the accompanying figure, and any of the lightning communicated to it, is conveyed away by the metallic rod which is led into the ground below. This rod ought not to terminate in a dry non-conducting body, but be conveyed if possible to moist earth or to a well, so that the electricity may be at once discharged into a good conducting medium.

202. In ships, the metallic conductors are usually fixed to the mast head, and continued down to the copper sheathing in contact with the water, where they terminate.

203. *Non-conductors* are bodies which have comparatively so

very feeble a conducting power, that they resist the movement of electricity through their particles, or at least only transmit it with such extreme slowness, that they are familiarly employed to prevent its transmission. Glass, sulphur, resins, dry air, wood, paper, hair, silk, and feathers, are all non-conductors.

Fig. 15.



204. The electric *circuit* is the course that electricity takes in passing from one body to another. It is said to be *broken*, or *interrupted*, when the progress of the electricity is arrested or retarded by separating at any point the conducting materials through which it passes, or by interposing any non-conductor between their extremities where the continuity is broken.

205. A body is said to be *insulated* when it is placed on a non-conductor, so that it can neither give electricity with facility to external objects, nor receive it from them.

206. When any body electrically excited is opposed to an-

other in its natural state, the latter assumes an electric condition, exactly opposite to that of the first to which it is opposed.

207. Changes of this kind, effected merely by proximity to an excited body, are called cases of the *induction of electricity*, and the electricity is said to be *induced*. Hence a body, presenting no electrical phenomena, and without any change in the amount of electricity in it, may, in a moment, by a mere change in the distribution of the electricity it contains, caused by the approximation of any body electrically excited, have the arrangement of the electricity in it so altered as to become positively electrical at one extremity, and negatively electrical at the other.

208. In the common electrical machine, electricity is developed by the friction of a hair-cushion covered with an amalgam, which affects the air chemically, as the cushion presses upon a glass cylinder or plate which is made to revolve rapidly. The electricity becomes accumulated in the glass; small and pointed metallic wires attract it and convey it from the revolving glass to a large metallic vessel, *insulated* by being placed on a non-conductor. Were it placed on a conductor, the electricity would be restored to the ground as fast as it might be transmitted to the prime conductor. The hair-cushion must be connected with the ground by a good conductor, that fresh electricity may be conveyed to it from the earth, as fast as it is withdrawn. Electricity is taken from the prime conductor by approaching to it the body to which it is to be applied.

209. The *Leyden jar*, named from *Leyden*, where it was invented, consists of a jar in which electricity can be accumulated in larger quantity than in the prime conductor. It is coated with tin-foil externally and internally, except towards the upper part. A rod terminating with a ball passes through the upper part, the lower part of the rod being connected with the interior coating by a chain. When the ball is approached to the prime conductor, electricity accumulates in the interior coating of the jar, and this causes electricity to be repelled by induction from the exterior coating. There is, therefore, a great difference established between the electricity of the interior coating, which has more than its usual share, and that of the exterior coating, which has less. The uncoated glass prevents any freedom of communication between them. If a metallic communication be now established between the ball and the external coating, electricity is conveyed rapidly through it to the external surface, and an equilibrium is restored. Any materials subjected to the influence of the electricity of the jar, must be made to form part of the circuit through which it passes.

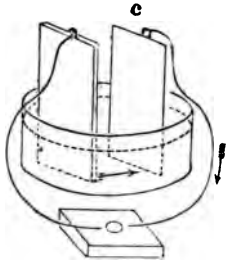
210. Rub a large stick of sealing-wax briskly with a silk handkerchief; electricity is produced, and light substances, as a feather or a small piece of paper, are attracted by the wax. If the experiment be performed in a dark room, small sparks of electricity may be observed on approaching the finger to the wax.

211. Repeat this experiment, using a stout glass tube instead of the sealing-wax.

212. For ordinary chemical purposes, electricity is developed more conveniently by galvanic arrangements than by the electrical machine. In these the mutual action of different particles of matter brought into play, so as to produce chemical changes, is accompanied by the development of a large quantity of electricity.

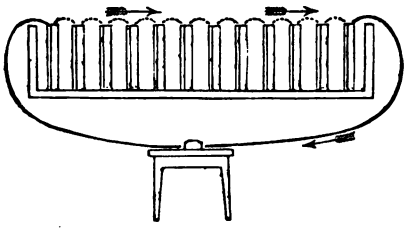
213. Fig. 16 represents one of the most simple arrangements adopted for this purpose. A plate of zinc and a plate of copper are immersed in an acid liquid capable of affecting one of them; the electricity passes from the zinc to the copper through the liquid; the circuit is established by wires connecting these two plates externally. Any matter to be affected by the electricity must be placed between their extremities, as is represented in the figure.

Fig. 16.



214. Fig. 17 shows a section of a galvanic trough, in which

Fig. 17.

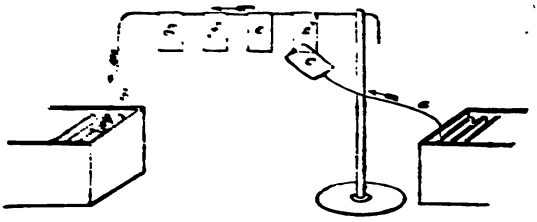


the united action of any number of pairs of plates may be obtained.

215. Fig. 18 shows part of a still more complicated arrangement, such as is used where the united action of a number of troughs is required, all of which act in the same manner as if

they had been formed into one trough and properly connected by metallic wires. One extremity, *a*, is represented in connexion with a metallic plate, held below one of the metallic leaves *d*, *e*, *f*, *g*. These are placed upon a metallic rod resting on a non-conducting glass support, and attached by *b* to the other extremity of the troughs. If the plate, *c*, be applied

Fig. 18.



successively to each of the metallic leaves, they are dissipated in vapour with the evolution of much heat and light. Very thin leaves of gold, silver, copper, and tin, should be used for this purpose. When a number of troughs are connected together, and used simultaneously, the apparatus is termed a *galvanic battery*.

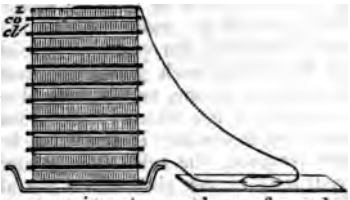
216. In any galvanic arrangement, whether one or many troughs be used, the zinc and copper plates, which are arranged so as to compose the cells, must be placed in one unvarying order, the zinc and copper succeeding each other alternately throughout the whole series. A pair of zinc and copper plates are usually soldered together, the cells being formed by the zinc plate of one pair and the copper plate of another.

217. The cells are usually charged with acids diluted with from ten to fifty parts of water. The greater the intensity of action required, the stronger ought the acid to be. In some batteries, as in that used by Mr Grove, where a complicated but very effective action is maintained, concentrated acids are employed.

218. On a smaller scale, a very simple arrangement, usually termed the galvanic pile, may be made in the following manner:—Procure twelve plates of copper and twelve plates of zinc, place them in the order represented in fig. 19, with a piece of cloth between each pair, the upper and lower plates having copper wires soldered to them, tipped at the extremity with small wires of platinum. The plates need not be more than two or three inches in diameter, and the cloth must be moi-

tened with a liquid composed of 1 part, by measure, of sulphuric acid, 2 of nitric acid, and 60 of water. The whole of the apparatus may be placed in a small plate or basin. Sometimes each zinc plate is soldered to a copper plate; they can be arranged more conveniently in this way than when separate. With this apparatus the following experiments may be performed.

Fig. 19.



219. Place any of the substances mentioned in the succeeding paragraphs, in solution upon a small slip of glass or paper; a drop of the solution will be sufficient. The platinum extremities of the two wires must be dipped into the solution, but not so as to touch each other. The electricity is developed as the acid fluid in the cloth acts upon the zinc, accumulating in one of the wires and passing to the other, the materials in the solution being affected as it passes through and decomposes them.

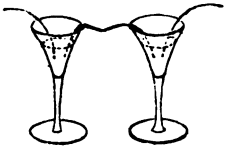
Materials used.	Products.
1. Sulphate of soda, composed of sulphuric acid and soda, resting on cabbage-paper.	1. The acid accumulates at one wire, and reddens the paper; the alkali at the other, and turns it green.
2. Iodide of potassium, composed of iodine and potassium, mixed with a little starch.	2. The iodine is immediately separated, and forms a blue compound with the starch.
3. Acetate of lead (common sugar of lead).	3. Metallic lead is deposited in small crystals.
4. Sulphate of copper.	4. Metallic copper is deposited in the same manner as the lead.
5. Hydrochlorate of tin.	5. Metallic tin is deposited in crystals.*

220. Put a teaspoonful of sulphate of soda into a cup, and dissolve it in hot water; pour a little cabbage-blue (see Colour-

* The *electrotype* is a process where, by arrangements similar to those by which the preceding metals are deposited from their solutions, a metal is made to fall upon any mould, and take the impression of any type, seal, or other figure, which may be required.

ing Matter) into the solution, and put a portion into two glasses, connecting them, as represented in fig. 20, by a piece of linen or cotton cloth, previously moistened in the same solution. On putting one of the wires into each glass, the acid accumulates in one, turning the blue to a red, and the alkali in the other rendering it green. If the wires be now reversed, the acid accumulates eventually in the glass where the alkali appeared, while the alkali passes to the glass where the acid was.

Fig. 20.



221. Moisten the fingers with the diluted acid used for the cloth, and hold one wire in each hand; the electricity is felt feebly as it enters the fingers, and passes through the body from one wire to another. With a large apparatus, the most violent convulsive movements, and even death, may be produced.

222. Electricity passes readily through metals and charcoal, and is attracted by all pointed objects in great quantity. Hence, in a thunder-storm, all elevated situations and metallic bodies should be avoided; it is dangerous also to be near trees, as the electricity frequently passes down by them to the earth. The safest place in a thunder-storm is the middle of an open field, at a distance from all high objects; or at home, in the middle of a room, away from the walls, the chimney, and the window.

CHAPTER XI.

WATER AND ITS ELEMENTS.

223. Water, or oxide of hydrogen, is composed of hydrogen 1 + oxygen 8; equivalent 9. W. of 1 cubic inch, 252·458 grs. For the action of heat upon it, see Liquefaction and Vaporisation.

224. Pure water is transparent, colourless, tasteless, and inodorous, and leaves no residuum when evaporated to dryness. Its compounds are termed *hydrates*, or *aqueous combinations*. It dissolves numerous vegetable, animal, and mineral substances; and is decomposed in many cases of chemical action, affording oxygen or hydrogen to the substances which affect it. It also absorbs or condenses many gases, most of which are expelled on boiling.

225. As a chemical agent, there are few bodies of greater

importance either in the great operations of nature or in the processes of art. In the ocean, it not only affords the medium of life and activity to one portion of the animated creation, but appears also to have been an agent by which vast changes have been effected, and are still carried on at the surface of the globe, reducing in particular great and massive rocks to a minute state of division, and preparing them so as to form that soil which is so essential for the productions of the vegetable world, and equally necessary, from the products which it affords, in sustaining animal life. Its power of solution is very remarkable, and many of the rocks or strata deposited from the ocean appear to have in some cases subsided, after having been mechanically suspended in water, while in others they have been separated by a species of deposition or crystallisation, such as may be induced artificially on the small scale in numerous chemical processes to which water is constantly subjected. Again, from the immense and extended surface of the ocean, part of the water is continually passing into a state of vapour, when it is separated from the various materials with which it is associated in solution; and being thus distributed over the surface of the land by the movements it is subjected to as it travels invisibly in the air, or in the form of a cloud, is ultimately deposited, free from impurities, at the surface of the globe, nourishing animal and vegetable life as it falls in the rain or the dew-drop, while it also acts chemically upon numerous ingredients that are observed in the mineral kingdom.

226. *Pure water*, for chemical purposes, is prepared by distillation (see 146), as it is nowhere obtained absolutely pure in nature; the impurities remain in the retort or still. Rain and snow-water are the purest natural waters; even these must be boiled to expel air, when water is required absolutely pure.

227. For ordinary purposes, water may often be purified to a certain extent without distillation by filtering it through beds of gravel and sand, and still more effectually by the action of animal charcoal, which absorbs or destroys numerous offensive matters that are often associated with it. Ordinary charcoal has a similar effect, but is much less powerful than animal charcoal, probably from the absence of a minute quantity of lime which the other is known to contain along with various salts.

228. Some varieties of water, as the water of the Thames, undergoes considerable changes when kept for some time in casks at sea or in other situations, the animal and vegetable matter it retains in solution, after impurities merely mechanically suspended have been removed by filtration, producing a kind of fermentation when they are in a great measure decom-

posed; the water then becomes fit for use. Iron tanks have been much used of late for holding water on board ships, and might be adopted with advantage in other situations. In them good water may be preserved for any length of time, if the air be excluded. Leaden vessels may be used without injury for holding some varieties of water, when the saline matter in the water forms an insoluble compound with the superficial particles of the lead, adhering to it closely, and protecting it from further injury. But other varieties of water it is very dangerous to place in leaden cisterns, as they corrode the lead, and suspend a portion of it in a minute state of division, becoming then highly poisonous; the suspended lead is considered in general to become a carbonate, acquiring carbonic acid and oxygen from such waters; and in this condition, being in an extremely minute state of division, it is suspended with comparative facility. No water ought to be kept in leaden cisterns for ordinary purposes, without previously ascertaining its chemical qualities and its disposition to corrode the lead. Whole villages have suffered severely from the effects of lead, where pipes of this material have been incautiously substituted for others made of earthenware or wood.

229. *Spring water* is not so insipid and tasteless as distilled water, containing portions of air, as well as saline or earthy matter which it may have dissolved while flowing in contact with various rocks and minerals. *River water* is similar to spring water, but oftener loaded with impurities. *Well water* is still less pure. Water is said to be *hard* when it is so loaded with foreign matter that it decomposes soap, producing a curdy precipitate, so that it is unfit for washing, or for dissolving many substances in daily use.

230. *Mineral waters* include all those which are so charged with foreign matter as to acquire peculiar properties. The following are the principal varieties of mineral waters, and their properties should be studied along with the properties of those substances in which they abound. These are printed in italics; and by referring to them as they are described in succeeding chapters, the tests by which they are distinguished will be seen.

I. Acidulous mineral water abounds in *carbonic acid.*

II. Sulphureous mineral water contains *sulphureted hydrogen.*

III. Saline mineral water contains principally *soda, lime,* or *magnesia,* united generally with *sulphuric* and *hydrochloric acids.*

IV. Chalybeate mineral waters contain *iron,* united with *sulphuric* or *carbonic acid.*

231. To acquire at once a general knowledge of the properties of any water, the following experiments may be tried :—

I. Evaporate a drop on a flat slip of glass, holding it before the fire, or above a small lamp or candle. Small thin rings appear where the water rested, if it contained only a minute quantity of foreign matter; but a crust is seen, if it be loaded with saline or earthy matter; the crust has a brownish-yellow tint if iron be present. All ordinary varieties of water containing variable quantities of saline or earthy compounds in solutions, a crust, or sediment, is always left when large quantities are evaporated. In steam-engine boilers this is particularly observed, the crust requiring to be removed periodically, otherwise the deposition is so great that the communication of heat is altogether arrested through the thick mass of earthy matter that rests upon the bottom of the boiler.

II. Pour some of the water into a wine glass, and add a solution of litmus; it is reddened if any acid matter be present.

III. Mix another portion with a little soap; a curdy substance appears if it abound in earthy matter.

232. Many waters may be purified to a great extent merely by boiling, when carbonic acid and sulphuretted hydrogen gases are at once expelled, if not retained in solution by soluble compounds with which they may be combined. In waters abounding in lime and iron dissolved by carbonic acid, the most marked effect is produced by boiling, much of the carbonic acid being at once expelled, while the lime and iron are separated in combination with part of the acid in the solid form, the water being left altogether, or at least comparatively, pure.

OXYGEN.

233. This element is a gas. It is 16 times heavier than hydrogen, and forms more than one-half of the globe, constituting 8 tons in every 36 of air, 8 in every 9 of water, nearly a half of the more abundant earths, silica and alumina, besides being found in almost all vegetable and animal matters. It received the name of oxygen from Greek words, signifying to produce a sour substance, many of its compounds being acid.

234. *Oxides* are compounds of oxygen which are not acid. *Oxidation* signifies the union of any body with oxygen. Substances which communicate oxygen with facility to other matters, are called *oxidating agents;* the principal are air, water, and acids and salts containing oxygen. *Deoxidating agents* include those substances which are powerful in removing oxygen, as carbon, hydrogen, phosphorus, iron, and many other metals.

235. Oxygen is particularly distinguished by its power of

supporting combustion; all inflammable substances burn brilliantly in it. It is not known, however, in what manner heat and light are evolved, as the particles of the combustible body affect the particles of the oxygen, and combine with them. Some bodies are warm enough to take fire at natural temperatures, and are never, accordingly, observed under ordinary circumstances at the surface of the earth; but in others a very various degree of heat is required to produce actual combustion. Phosphorus takes fire at a temperature of 100 degrees, sulphur at 300 degrees, and carbon at various temperatures between 280 degrees and the high temperature of a white heat, according as it is used in the form of a light and porous charcoal, of a soft or hard coke, or of the diamond, in which the close aggregation of the particles renders it very difficult of combustion.

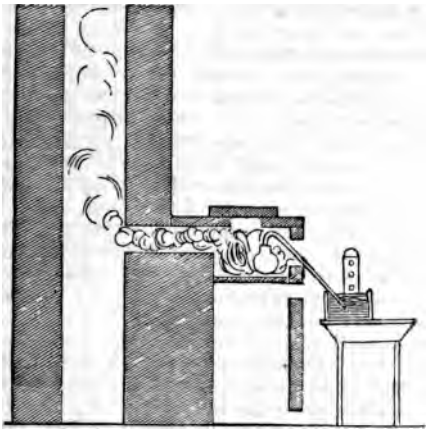
236. Besides that rapid combustion which is familiarly observed in a common fire, numerous inflammable substances, more especially phosphorus, a number of oils, charcoal, coals, and other substances, which can be reduced to a minute state of division, are prone to act slowly upon the oxygen of the air. This is more particularly observed if the materials used be accumulated in very considerable quantities, so as to expose an extensive surface to it by being arranged in heaps, or spread, if fluid (as when oils are used), upon cotton, tow, or saw-dust, so as to give a similar extensive surface, upon which the air can act in the various interstices, without allowing it to be carried too rapidly away from the different particles upon which it may impinge. The action of the air and the inflammable matter under such circumstances, is usually referred to under the title of *slow combustion*; and all cases of this kind ought to be very carefully studied, as the accumulation of heat from this cause frequently increases to such an extent, that the materials ultimately burst into an active and vivid combustion. Numerous fires, both on board ship and on shore, particularly in manufactories where oil, tow, cotton, and machinery are used, have been traced to this cause. Cases have been recorded where the materials have passed into a state of active combustion in a few hours; instances have also been authenticated in which nearly a year elapsed before the fire appeared.

237. Introduce a wooden match, red hot at the end, into a jar of oxygen, or a suspended candle (fig. 21) with the wick red; it burns brilliantly, and the flame is rekindled. In all cases where ordinary inflammable matter burns, it acts upon the oxygen which is contained in the air, and combines with it. The inflammable matter is not lost or destroyed, but often becomes invisible like the air itself, as it forms gaseous compounds.

Fig. 21.

238. PREPARATION.—Binoxide of manganese is heated to redness in an iron bottle placed in an open fire, or resting in a furnace, as in the annexed cut, fig. 22. The bottle should be

Fig. 22.



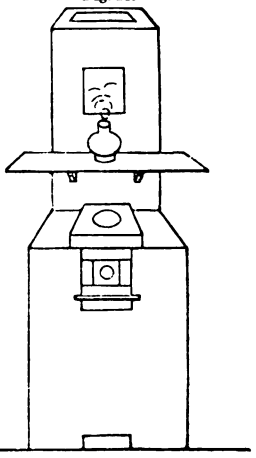
large enough to contain several ounces of the binoxide; and the oxygen which is not required for immediate use, should be collected in beer bottles previously filled with water, and employed afterwards as it may be required. The bottles should be corked under water, the corks being afterwards covered with lard, and a piece of cloth tied round them.

239. When the binoxide is contaminated with carbonate of lime, or other carbonates, carbonic acid gas is evolved along with the oxygen. This gas is very different from oxygen, and much impairs its value. By using water in the pneumatic trough, to which lime has been added, the carbonic acid is absorbed, and retained in combination with the lime.

240. The furnace represented here is of a form extremely convenient for numerous operations; and, where the vent is exposed on every side, other furnaces may be placed around it. The area for the fuel may be made from 9 inches to a foot square, and the small chimney from 5 to 6 inches in diameter A front view is given in fig. 23, to show the manner in which the bricks are arranged in small pieces, so as to be taken out and adjusted according to the experiment to be performed. The chimney works well if it be 9 or 10 inches square, and from 10 to 20 feet high. A shelf is placed before and below

an aperture in the chimney; and when it is required to carry off fumes from any mixture, it is placed in the situation occupied by the flask, the plug being removed from the aperture, which is at other times closed.

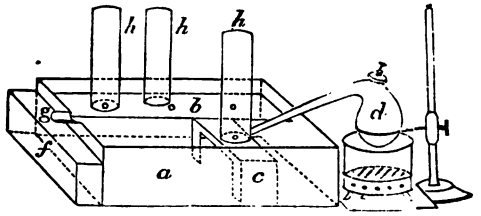
Fig. 23.



241. When the binoxide is heated in the furnace, 88 grains give 8 of oxygen, and every grain may be considered as equal to 3 cubic inches of gas.

242. Where there is no opportunity of operating with a furnace, 1000 grains of the binoxide in fine powder may be mixed in a retort with an equal weight (about $1\frac{1}{4}$ ounces by measure) of aqueous sulphuric acid; in this case every 44 grains give 8 of oxygen; but this process is not so well adapted for preparing a large quantity of oxygen. The retort must be heated by a chauffer or lamp, and the heat withdrawn whenever the gas ceases to escape, otherwise the water might pass into the retort and break it, being forced up by the pressure of the air as the gas still in the retort cools and contracts.

Fig. 24.



243. The trough *a* (fig. 24.) is usually made of wood or tinned iron, about 24 inches long, 12 broad, and 8 deep. The shelf *b* and moveable stool *c* may be made 7 inches high. The pneumatic jars *h h h* being filled with water, gas is prepared from the retort *d*; the spout *g* discharges any excess of water from the jars as they are filled with gas, the water passing into the small trough *f*.

244. Zinc trays (fig. 25) or small plates are placed below the jars of gas under water, when they are to be removed from the trough, and used for experiments. The jars or bottles used for collecting the gas must always be filled with water to expel air, before any gas is collected.

Fig. 25.

245. Jars of this form (fig. 26), are often used to transfer oxygen or other gases to a bag or bladder, adjusted mutually to each other by moveable connectors. The jars being filled with gas, and then depressed in water, the gas is forced into the empty bag, which is slowly distended. The bag having been withdrawn, a nozzle is fitted to it (fig. 27), by which the gas can be directed upon any object when it is compressed.

Fig. 26.

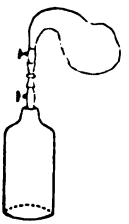
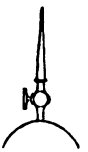


Fig. 27.



HYDROGEN.

246. Hydrogen is a gas, and the lightest of all known substances; it is nearly 14½ times lighter than air; 100 c. i. weigh only 2 grains and a fraction. Its name is derived from two Greek words signifying to produce water, as that fluid is formed when 1 part of hydrogen unites with 8 of oxygen.

247. Hydrogen constitutes 1-9th of the water of the globe, and is also found in almost all animal and vegetable substances.

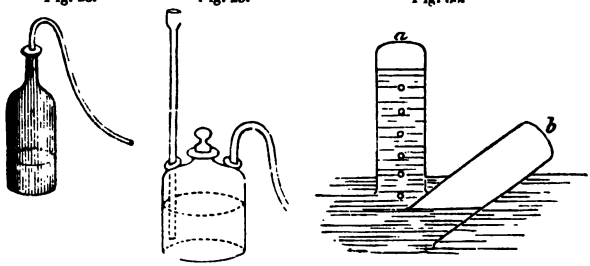
248. PREPARATION.—Put 500 grains of zinc in fragments into a common beer-bottle; pour upon them 3 ounces of water, and add 5 drachms of aqueous sulphuric acid. The acid, the oxygen of part of the water, and the metal, combine, producing sulphate of zinc; the hydrogen is disengaged, and may be collected at the pneumatic trough in jars; a cork with a bent tube is adapted to the neck of the bottle (fig. 28) to convey the gas to the jars, which can be arranged as in fig. 24.

249. Zinc is procured in fragments by melting it, and pouring it from a height into water. Iron-filings may be substituted for zinc; the acid should then be added slowly, and an apparatus of the form shown in fig. 29 is convenient, as it may be introduced by the long tube in small quantities at a time, to prevent the action going on too briskly. Small nails may be used instead of the filings.

250. Invert a jar with hydrogen, after covering the mouth with a tray or cover, and apply a lighted match as the cover is taken off; the hydrogen burns rapidly, uniting with the oxygen of the air, and producing water.

251. Inflame hydrogen gas in another jar, keeping the mouth downwards; the light hydrogen mixes this time more slowly with the air, and takes a longer time to burn.

Fig. 28. Fig. 29. Fig. 30.



252. Take any small jar or phial, fill it with oxygen, and then introduce the oxygen into a larger and very strong jar; fill the small jar twice with hydrogen, and mix it with the oxygen in the larger jar. Invert the mixture and apply a lighted match; an immediate detonation ensues, and water is formed.

253. Practise transferring gases from one jar to another under water, holding them as in fig. 30.

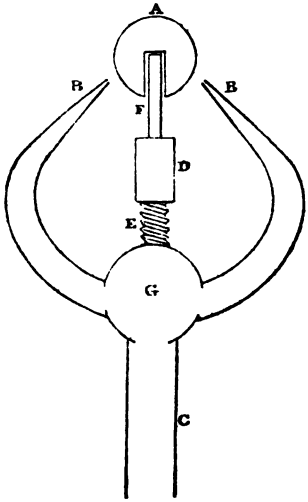
254. Transfer hydrogen into a bag with a small nozzle (fig. 27); press it so as to direct a stream upon a small portion of spongy platinum less than a pea, and supported loosely in a small coil of platinum wire; the air, or oxygen, acting on the platinum at the same instant with the hydrogen, the metal soon becomes red hot, and the hydrogen is inflamed.

255. If two bags be taken, one with oxygen, the other with hydrogen, and a stream of gas be pressed out from both at the same instant, so that they unite and produce one jet of flame, an intense degree of heat is excited; this apparatus is usually termed the *oxyhydrogen blowpipe*. Iron-wire held in the flame quickly burns; small fragments of copper, zinc, antimony, lead, and tin, burn with great rapidity, if supported on charcoal; small pieces should be taken, less than a pea. Lime, tobacco pipe-clay, and other earthy substances, become intensely luminous in this flame. The hydrogen requires only half its bulk of oxygen to be mixed with it; and the gases are apt to explode if they be mixed in one vessel, unless the tubes be arranged in a particular manner to prevent the flame from returning. The figure shows the manner in which the nozzles from the bags are connected in

Fig. 31.

her nozzle, at the extremity of which the flame is pro-
d. These nozzles are usually made of brass, and about
th of an inch in diameter at the extremity, or rather less.
6. An excess of hydrogen should always be used, as it
ers the small portion of the mixture within this nozzle
h less liable to explosion; as a farther security against the
trifling explosion that might be produced by any return
he flame into this nozzle, containing the mixed gases, it is
a filled with numerous layers of wire-gauze.
7. In experiments on a larger scale, gasometers or reser-
s for the separate gases are employed, and Dr Hare, who
duced the use of the oxyhydrogen blowpipe, has for some
s used it for melting platinum, a metal that is not conve-
tly fused in furnaces worked with common fuel.
8. When a very intense light is required, so that it shall
oncentrated within a very limited space, it is produced in
ral by directing a number of small jets of flame from the
hydrogen blowpipe upon a ball of lime, supported in the

Fig. 32.



ner represented in the annexed figure. So intense is the evolved, that it has been seen in a clear night at the dis- of ninety-six miles. A, the lime-ball · B one of a num-

ber of nozzles proceeding from the centre G; C, the stem of the blowpipe containing the mixed gases; D, the support for the ball, terminating in a platinum rod F, and moving upon a screw E, so that it can be adjusted to a proper height.

259. Symbols of processes described, with a translation:—

H&Ö = ·H. Hydrogen and oxygen produce water.

:S&·H&Z = :S·Z&H. Sulphuric acid, water and zinc, produce sulphate of zinc and hydrogen.

:S&·H&Fe = :S·Fe&H. Sulphuric acid and water, and iron, produce sulphate of iron and hydrogen.

CHAPTER XII.

AIR AND ITS ELEMENTS.

260. Air is not an element, but a compound of two gases, oxygen and nitrogen, and its chemical properties depend principally upon the oxygen it contains. The oxygen combines with inflammable matter during combustion, it acts on the blood in the lungs when animals respire, and its influence may be traced in numerous operations continually going on at the surface of the earth. When the oxygen of the air is consumed, inflammable substances do not burn in it, and animals introduced into it immediately die. Hence the great importance of removing air vitiated by combustion or respiration, and introducing into every apartment fresh air from a pure source. Much of the oppression and headache of which many persons at times complain, either arises entirely, or at least is much aggravated, by breathing for a great length of time in an atmosphere vitiated by a crowded assembly, or imperfect ventilation.*

261. Minute quantities of moisture and carbonic acid are found in air in every part of the globe, which have an important influence in numerous changes at the surface of the earth; and though large quantities of oxygen must be continually consumed, still the composition of the air does not vary, oxygen being again restored to it, principally, it is believed, by the action of the leaves of plants during sunshine.

262. Put a lighted candle, about two or three inches long, upon the shelf of the pneumatic trough (fig. 21), supporting it above the water on any small metallic stand (fig. 33). Place over it a glass jar eight or ten inches long, allowing it to rest upon the shelf. The air in the jar is at first expanded by the heat, and a little escapes; the candle soon begins to burn more dimly as the inflam-

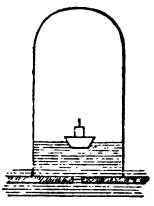
Fig. 33.

* For illustrations of ventilation, see Carbon, Fire-places, and Furnaces.

mable matter it contains consumes the oxygen, and in a short time it is extinguished. Water is now forced up by the pressure of the external air to supply the place of the air expelled at first, and also of part of that which is consumed, a portion of the product being condensed by the water.

263. Repeat this experiment, using a candle supported on a cork, so as to float upon the surface of the water, as in the annexed figure.

Fig. 34.



264. Again repeat this experiment, using nothing, however, but the candle and the glass jar, previously dried with great care, the candle being put on a table, and the jar placed over it.

265. In all these cases a large portion of the oxygen of the air is consumed, uniting with the hydrogen, and also with the carbon, which form the principal ingredients in wax, oil, and tallow. The water that appears in innumerable small points or drops upon the sides of the dry jar, is formed by the union of the hydrogen of the candle with the oxygen of the air; the carbonic acid gas is formed as the carbon unites with oxygen, and this may be easily detected by the addition of lime-water, which is immediately rendered turbid by the carbonic acid, if a few ounces be agitated with it in the jar.

266. In studying the action of air upon different chemicals, and still more especially in viewing its effects upon the human frame, the following memoranda will be found useful:—

267. Air, at a temperature varying from 60 to 65 degrees, is found to be most congenial to the greater number of constitutions in this country, if it move so gently that fresh quantities are continually conveyed to the system without any sensible impetus, or at least without producing any offensive current. Different constitutions vary much as to the temperature that is most suitable for them. A difference of 24 degrees is observed in extreme cases as to the temperature preferred by different persons; and, even in the same individual, a very great difference may often be seen as to the temperature that is preferred, according to the state of the constitution at different times. As age advances, and the bodily strength diminishes, a temperature from 63 to 68 degrees is found most agreeable.

268. Air, at a high temperature, provided that be below the temperature of the body, may produce the same amount of cooling power as air at a lower temperature, if it be made to move more rapidly, so that a larger quantity of it shall be brought in contact with the system in a given time. Hence,

air at a given temperature may feel agreeably warm or very cold, according to the rapidity with which it moves upon the person. Temperature, therefore, considered independently of the velocity or slowness of movement in the air, is no guide as to the precise manner in which it is likely to affect the feelings. Air may be perfectly pure in respect to its proportion of oxygen and nitrogen, but may be vitiated by the presence of moisture in unusual quantity, when it arrests insensible transpiration, and affects seriously the functions of the skin.

269. On the other hand, air may be so free from moisture, that it may withdraw moisture rapidly from the system, and produce injurious effects by its extreme dryness. Air is more largely charged with moisture in summer than in winter, but has less tendency to deposit that moisture, in consequence of the high temperature.

270. In winter, though the amount of moisture in the air may be less, it is apt to become more offensive from the facility with which it is separated in a palpable form.

271. In addition to those changes that result from a difference of temperature, air is apt to vary greatly in its influence upon the human frame, according to its electrical condition, which has not hitherto been studied so minutely as its importance requires. Further, the following materials may be found in the air in different districts, in very variable porportions, or only in particular localities, according to the nature of the source from which they are evolved.

272. *Carbonic acid;* carbon, the principal ingredient in all animal and vegetable substances, tends ultimately to become carbonic acid gas as they fade and decay, when it is diffused through the air and absorbed by the leaves of plants, or by water which approaches their roots, and again presents it as a source of food in the vegetable kingdom. In a proportion of about 1-1000th part, it is found every where in the atmosphere; in old wells and pits it is often so abundant that certain death ensues when any one incautiously visits those in which it is accumulated.

273. *Carbureted hydrogen* is found principally in coal mines, or escaping from strata in which coal, tar, naphtha, and other inflammable substances, abound.

274. *Sulphureted hydrogen* is noticed more particularly in the vicinity of sulphureous waters, and where compounds termed sulphates are left in stagnant water and in contact with animal or vegetable matter.

275. *Sulphurous acid* may also be observed near active volcanoes, copper works, and large cities. In Wales, 80,000 tons of sulphur are annually consumed and discharged, after being

dissipated in the form of sulphurous acid, from four works alone in which copper is separated from the ore.

276. *Minute particles* of exceedingly fine *dust* are noticed principally when a tempestuous atmosphere blows upon a sandy desert, or when they are projected from active volcanoes. In some cases the dust has covered the decks of ships at some distance to the depth of half an inch or more, and instances are recorded where it has been deposited in large quantities at a distance of 400 miles from the volcano by which it was discharged.

277. *Salt* is noticed more particularly towards the sea-coast, but has also been found encrusting leaves at a distance of 200 miles from the sea. It is supposed to be derived from the spray of the sea, agitated greatly during a heavy gale of wind.

278. *Malarious matters* are the offensive products that arise from various soils and marshes, and from animal and vegetable matter generally, in a state of decay. Thousands die annually from its injurious influence, but its precise nature is unknown, and probably there are many varieties of malaria, each having peculiar properties. It has been supposed that many minute and invisible animalculæ sometimes produce diseases attributed to malaria, while offensive gases, or, at all events, offensive compounds which are soluble in gases, such as are met with at the surface of the earth, have also been considered to produce these effects. By the action of a high temperature, by the agency of chlorine, of lime-water, and other substances, attempts have been lately made to diminish the virulence of the action of malarious poisons, but until their precise nature shall have been more accurately investigated, it will be impossible to propose specific plans for destroying its influence in each individual case.

279. Numerous substances, as arsenic, copper, hydrochloric acid, and other bodies, may be traced in endless variety in some situations, especially in the vicinity of particular manufactories. Air in large cities, such as London and Manchester, is often largely contaminated with soot. In the worst cases in these places, nearly 400 separate pieces of soot have been observed to fall within a few hours upon a square foot of surface.

280. In most buildings the supply of air is taken too frequently from the most indifferent sources, while the due discharge of the vitiated air is equally uncontrolled. The higher the source from which air is taken, the better is it in general, and the more free from exhalations from drains, &c.; care must be taken not to lead it from the same level as that of chimney tops in the vicinity.

NITROGEN.

281. This gas abounds in the air, forming 4-5ths of its bulk, and is also found in considerable quantity in animal substances, and in salts called nitrates. It is observed only in a few vegetable substances.

282. Put 8 or 10 grains of phosphorus into a tin or copper cup, supported several inches high (fig. 35), and place over it, when inflamed, a jar about the size of a common beer-bottle, operating at the pneumatic trough, as in fig. 24. The phosphorus should never be touched directly with the hand, and must be dried well between folds of blotting-paper before it is used. When the white compound of the phosphorus and oxygen of the included air has combined with the water, nitrogen gas remains, transparent and colourless.

Fig. 35.

283. Transfer it under water to another jar, previously filled with water, holding them in the manner shown in fig. 30; or invert the jar with a cover, keeping in all the water, and introduce a suspended candle (fig. 21) into the gas; it is immediately extinguished. The nitrogen may be contrasted with oxygen in another jar, the candle being extinguished in the one, and rekindled in the other, many successive times.

284. Nitrogen neither supports combustion nor respiration. It is disengaged with great facility from numerous compounds, many of which explode violently as it is separated.

NITRIC ACID.

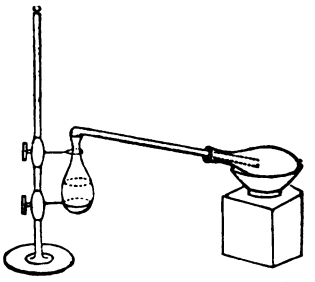
285. The elements of air, united in a different proportion, form nitric acid, one of the most corrosive and powerful acids; diluted with water, it constitutes aquafortis.

286. Compounds which have a sour taste, and redden blue vegetable colouring matter, are termed acids, though a few of them are very feeble in these respects.

287. Fill a glass retort about one-third full of a mixture of equal weights of aqueous sulphuric acid and nitrate of potassa (common nitre); heat the mixture with a lamp or chauffer, and collect the vapour that distils over in a receiver, which must be kept cold; if the vapour comes over more rapidly than it can be condensed, the heat must be moderated

288. A flask with a bent tube fitted to it may be used instead of a retort, being luted to it with a mixture of clay and sand, when the materials have been introduced. (Fig. 36.)

Fig. 36.



289. The process should be continued till a quantity of acid be obtained, at least equal in bulk to the aqueous sulphuric acid employed. Part of the acid is generally decomposed, and a ruddy vapour produced which tinges the acid of various hues; it is called nitrous acid. The sulphuric acid remains in the retort with the potassa of the nitre, and the nitric acid passes into the receiver united with water, which it takes from the aqueous sulphuric acid employed.

290. Add a drop of the acid to water in a beer-glass, coloured with vegetable blue; it is immediately reddened.

291. Cover a tea-spoonful of iron-filings in another beer-glass with water, and pour upon them small quantities of acid at a time till a brisk effervescence appears. The iron takes oxygen from the acid, and many gases are disengaged, composed of nitrogen with less oxygen than is found in the acid.

292. Heat two table-spoonfuls of charcoal powder to redness in a crucible, and pour upon it aqueous nitric acid in a very slender stream; the charcoal burns rapidly, taking oxygen from the acid.

293. Nitric acid is always associated with water as usually procured, and should be kept carefully in stoppled phials, as it is very corrosive, and emits acrid fumes. It is transparent and colourless when there is no nitrous acid present, and if concentrated, a phial that holds 1000 grains of water will contain about 1480 of this acid. It is often contaminated with sulphuric acid or chlorine, which may be detected by solutions of nitrate of baryta and nitrate of silver. The acid should be diluted in a wine-glass, before the tests are applied, with 6 or 8 times its bulk of distilled water. The tests produce no effect in pure acid; sulphuric acid gives a white precipitate with baryta, and chlorine produces the same effect with the silver. The tests must be tried in separate glasses.

294. Evaporate a portion of the nitric acid on a broad slip of glass, or in an evaporating basin, till none is left. If any solid matter remain, it is also to be regarded as an impurity.

295. The other compounds of nitrogen and oxygen are represented in the table, page 21. They are produced when nitric acid or its compounds are decomposed.

296. *Oxide of nitrogen*, commonly called Intoxicating Gas, can be respired for a minute or two without danger; it produces great excitement in general, accompanied by immoderate laughter, and violent muscular action. Its effects pass away very quickly.

297. It is prepared by decomposing nitrate of ammonia, which is resolved into this gas and water on subjecting it to heat in a retort, the water being condensed at the pneumatic trough, while the gas is collected in jars. The diagram, page 21, illustrates the precise nature of the changes that ensue.

298. *Binoxide of nitrogen* is also gaseous, and, when mixed with air or oxygen, produces dense, acrid, ruddy fumes of nitrous acid. It is obtained by the action of copper or mercury on diluted nitric acid, the metal removing part of the oxygen from a portion of the acid, and liberating the gaseous binoxide, while the undecomposed acid combines with the oxidated metals.

299. Nitrous acid generally appears as a ruddy vapour when nitric acid is decomposed, or when the binoxide acts on the air and attracts more oxygen.

CHAPTER XIII.

SULPHUR AND PHOSPHORUS.

300. *Sulphur* is a brittle solid, having a fine straw-yellow colour. It abounds in many volcanic countries, where it is believed to have been separated from its various compounds by the action of heat. It is also prepared artificially by heating compounds in which it is combined with metals. The most important compounds it forms with the preceding elements are sulphurous acid, sulphuric acid, and sulphuretted hydrogen.

301. Hold a roll of sulphur over a powerful lamp; it soon falls in pieces, the exterior portion expanding, while the rest is rigid. Sulphur is a bad conductor of heat.

302. Melt sulphur in a Florence flask, and pour it, whenever it is fluid, into water, it immediately becomes hard and brittle.

303. Heat another portion, after melting it, till it becomes thick and viscid; pour it, in a very slender stream, into water;

it is now transparent, soft, and elastic, but gradually returns to its usual form.

304. Heat sulphur in a small retort; the vapour condenses in the neck of the retort, or in a receiver which may be connected with it, in the form of a yellow powder, usually called Flour of Sulphur.

305. Melt sulphur in an earthenware cup, and allow it to cool; it consolidates into a crystalline mass. Observe the crystals as they shoot across the liquid. Dip small pieces of wood into melted sulphur; a portion of it adheres to the wood, and common sulphur matches are formed.

306. Pour melted sulphur upon a glass or other mould made of materials such as are not affected by the heat of the fluid sulphur. It takes a very accurate impression as it cools. Metallic substances are very apt to be discoloured by sulphur, and ought therefore to be avoided.

307. *Sulphurous acid* is formed when sulphur burns in contact with the air or pure oxygen. It is a pungent suffocating gas; water can condense thirty-three times its bulk, acquiring its odour. It becomes liquid when its temperature is reduced to 14 degrees; in this condition it evaporates quickly if exposed to the air, and produces intense cold. When sulphur is burned in oxygen, a very beautiful blue light appears. The same apparatus may be used as in burning phosphorus in air to prepare nitrogen (See 282), or a few fragments of sulphur may be kindled in a copper-cup, suspended by a wire (Fig. 37), and introduced into a phial, vase, or flask, filled with oxygen gas.

Fig. 37.

308. Sulphurous acid may be obtained in combination with water, but mixed in general with a little sulphuric acid, by heating 200 grains of mercury with an equal weight of aqueous sulphuric acid in a retort, and condensing the gas that is evolved by water placed in a flask or receiver. The sulphurous acid is formed as the mercury takes a portion of oxygen from part of the sulphuric acid; the rest of the acid combines with the mercury.

309. Sulphurous acid is particularly distinguished by its action on colouring matter. Numerous flowers are blanched when placed in a jar where sulphurous acid is slowly produced. Though the colour may fade and disappear, its basis is not destroyed, as, in many cases at least, it may be restored by the action of acid or alkaline vapours.

310. Sulphurous acid is formed in all ordinary cases not only where pure sulphur is burned, but also where many of its compounds are exposed to the action of heat and air, as in the Welsh copper works already referred to, par. 275, page 62.

The 80,000 tons of sulphur mentioned produce 160,000 tons of sulphurous acid gas, and part of the copper is also dissipated at the same time, destroying all vegetation in the vicinity, and even affecting animals with a peculiar disease termed popularly the *copper-smoke lameness*. In various other places, also, where different manufactories are carried on, numerous cases are pointed out where the deleterious action of the sulphurous acid, caused by the burning of the sulphur, has produced the most injurious effects, being equally inimical to animal life and to vegetation.

311. Sulphuric acid is the most important compound of sulphur, and is termed *aqueous sulphuric acid*, in the condition it is usually met with, about 40·1 of acid being combined with 9 of water. It is prepared by mixing sulphurous acid gas, formed by burning sulphur, with nitrous and nitric acid, in a large chamber lined with lead; the sulphurous acid becomes sulphuric acid after decomposing the nitrous or nitric acid, and attracting a portion of oxygen from it and the air. When properly concentrated, it is a dense oily-looking fluid, heavier than water. It is much employed in decomposing compounds containing acids, corrodes animal and vegetable matter, and is intensely acid. It reddens the vegetable blues.

312. Sulphuric acid, associated with other substances, is found abundantly in the mineral kingdom, more especially in combination with lime, soda, and magnesia. But though a virulent poison, and extremely corrosive of animal and vegetable matter, when concentrated and pure, it loses all these qualities on combination with the substances mentioned, when it produces successively sulphate of lime or plaster of Paris, sulphate of soda or Glauber's salt, and sulphate of magnesia or Epsom salt.

313. Sulphuric acid in solution is detected by adding a solution of lead or of baryta; a white precipitate immediately falls, which is not dissolved on adding diluted nitric acid. In earthy compounds not soluble in water, sulphuric acid is detected by heating them to bright redness in a crucible with powdered charcoal, after mixing them with a little pitch or oil, when a compound is obtained which produces a sulphureous odour, more especially on adding water and acids to it.

314. Pour three or four drops of aqueous sulphuric acid upon the fire, or upon a red-hot iron, where the fumes can be carried away; dense white vapours immediately appear.

315. Aqueous sulphuric acid should never be mixed with water in a glass measure, or any other thick glass vessel, as the sudden heat produced often causes them to be broken. Pour 3 ounces of water, by measure, into a thin flask, capable of holding 10 or 12, and mix with it in the flask 4½ ounces of the strongest acid. Great heat is immediately produced; if a

tube with cold water be placed in the mixture, it soon begins to boil. If the flask be very thin, it may be dipped into cold water till it is nearly covered, when, if it be immediately removed, the small portion of water adhering to the glass outside evaporates quickly, and much vapour is observed.

316. Put a few chips of wood into a wine-glass, and mix them with a little of the acid; the wood is decomposed, and becomes black from the separation of part of the carbon.

317. Take two beer-glasses with water, and put into each a drachm of the aqueous acid. Into one pour a few drops of any solution of baryta; sulphate of baryta falls, in the form of a white powder. To the other add a few drops of acetate of lead in solution, sulphate of lead immediately appears as a dense white precipitate insoluble in nitric acid.

318. *Hydrosulphuric acid*, or *sulphureted hydrogen*, is found in a number of springs, and in some cases, as on part of the coast of Africa, it is said to exist even in the waters of the ocean, producing the offensive odour observed in sulphureous mineral waters. It is gaseous when uncombined, and extremely noxious to animal life.

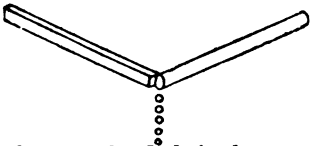
319. Air containing a proportion so minute as a millionth part of this gas is offensive to many constitutions, and must prove prejudicial to all. Air containing one part in fifteen thousand has been known to produce deleterious effects. A case is recorded where three stout men were obliged to give up work in an atmosphere containing only one part in five thousand. Air containing one part in fifteen hundred kills small birds. A horse dies in an atmosphere in which one part is mixed with two hundred and fifty of air. In a pure form, it produces instant death; in a more diluted state, the most violent convulsions are induced, which occasionally terminate in death.

320. Mix, in a bottle with a bent tube (fig. 28), 440 grains of the sulphuret of iron in fragments, with 3 ounces of water and 490 grains (5 drachms by measure may be taken) of aqueous sulphuric acid. Hydrosulphuric acid gas escapes with effervescence, and may be collected in jars or flasks at the pneumatic trough (fig. 24). The sulphur of the sulphuret takes hydrogen from part of the water producing the gas; the iron takes the oxygen with which the acid produces sulphate of iron; it remains with the undecomposed water.

321. Heat a bar of iron to whiteness, at a smith's forge, and press upon the extremity a roll of sulphur, inclining them in the manner represented in fig. 38, and collecting under water, in any iron vessel, the red-hot fluid which is immediately formed. It is the sulphuret of iron, very brittle when solid, and composed of 28 of iron and 16 of sulphur.

322. Invert a jar of hydrosulphuric acid gas, and apply a lighted match; the gas burns, and produces sulphurous acid and water as it acts upon the oxygen of the air; part of the sulphur is not consumed.

Fig. 38.



323. Fill a flask full of water, introduce a portion of the gas till it is half full, cork it under water, lift it out with the cork downwards, shake it well, and then loosen the cork, keeping the flask in the same position; the air rushes in to supply the place left vacant as the gas unites with the water. The solution is of the same nature with sulphureous mineral waters, but much stronger.

324. Moisten carbonate of lead with water, spread it upon a piece of paper, and introduce it into a jar or flask of the gas. The carbonate is immediately blackened, the dark coloured sulphuret of lead being formed, as the sulphur unites with metallic lead; at the same moment, the hydrogen of the gas combines with oxygen derived from the oxide in the preparation employed, and produces water.

325. Mix sulphate of lime (plaster of Paris) in fine powder with charcoal, and heat it to redness in a crucible after making the mixture into a ball with pitch or tallow (See 312 and 313). When cool, the mixture is found to have lost oxygen, the carbon having carried away, in the form of carbonic oxide, all the oxygen, both from the sulphuric acid and from the lime. It now smells strongly of hydrosulphuric acid, if water and an acid be added, for then the sulphur takes hydrogen from part of the water, while the oxygen of the decomposed water is attracted by the calcium of the lime; the acid added combines with the lime and liberates the hydrosulphuric acid.

326. A similar action ensues in liquids containing sulphates in solution, as Professor Daniell has very recently proved; and to this he attributes the production of diseases in numerous marshes and other situations where sea water, which contains sulphates, is left in contact with animal and vegetable matter in a state of decomposition; the carbon it contains produces the same effect on the sulphates in solution as the dry carbon used in the preceding experiments.

327. *Symb.* :S, Sulphuric Acid. ·H:S, Aqueous Sulphuric Acid. ·H:S&SFe = :S·Fe and HS. Water, sulphuric acid, and sulphuret of iron, produce sulphate of iron and hydrosulphuric acid.

328. *Phosphorus* is a very inflammable soft solid, having the appearance and consistence of wax. It melts at 100. and boils

at 550 degrees. When pure it is colourless, but more commonly it has a slight yellow tint.

329. Heat bones in an open fire, a white matter remains, composed principally of phosphoric acid and lime; by sulphuric acid the greater portion of the lime may be removed, and if the acid be now heated with charcoal, it removes oxygen, and the phosphorus is converted into vapour. This process is too complicated for beginners to attempt it.

330. Phosphorus being inflamed with great facility, it ought always to be cut under water, and never touched directly by the fingers; it gives a very severe burn when it touches any part of the body after it has been inflamed. When used in any experiment where no water is required, it ought always to be dried previously, by placing it between folds of bibulous paper.

331. Put 5 grains of dry phosphorus upon a tin cup, supported as in fig. 35, and placed upon a plate; inflame it, and cover it with a dry jar. The phosphorus unites with the oxygen of the air, and produces a solid acid, which falls down in the included air like flakes of snow.

332. Put 5 grains of dry and newly kindled phosphorus into a jar or flask full of oxygen, and capable of containing about 30 ounces of water; the phosphorus may be supported in a cup, and should be placed as low as possible in the vessel containing the oxygen. A very vivid light appears during the combustion of phosphorus in oxygen; an acid compound is formed, as above.

333. Place a thin slice of dried phosphorus (about $\frac{1}{4}$ of a grain) between folds of writing-paper, and rub it briskly with a glass-stopple. The heat produced by the friction soon inflames the phosphorus.

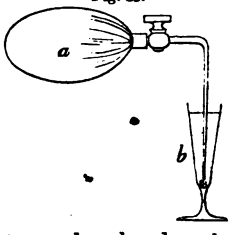
334. Cut under water ten slices of phosphorus, as thin, and not larger than the smallest wafers. Dry them cautiously on blotting-paper, taking care never to touch them with the hand, and then transfer them from the paper to a portion of tow or cotton, so that they may rest near each other. The tow or cotton being then placed on an iron cup, and covered with a jar to prevent external currents, the slow combustion which the phosphorus undergoes produces a white smoke which gradually increases, unless the temperature be very low, and ultimately the oxygen of the air is entirely consumed. Occasionally the phosphorus takes fire, illustrating what often takes place with other matters, as when oil, charcoal, and other substances, gradually absorb oxygen from the air, and produce a slow combustion, which terminates after a considerable lapse of time in an active and violent conflagration.

335. Melt 3 or 4 grains of phosphorus in a test tube, give heat till it boils for five or ten minutes, and allow it to cool. If a

sulphur match be now introduced, it may be made to rub off a portion of the phosphorus, the heat produced enabling the phosphorus to take fire on coming in contact with the air.

336. Put 10 grains of phosphorus into an ale-glass with boiling water, and force oxygen gas upon it, pressing out the oxygen from a bag in the manner represented in the annexed figure. The phosphorus inflames under the boiling water.

Fig. 39.



337. Heat 30 grains of phosphorus with 30 drops of water and 30 grains of aqueous potassa, in a very small retort, till a gas is evolved which inflames as it comes in contact with the oxygen of the air. When the gas comes steadily away, the beak of the retort may be placed under water. Every portion of gas which rises through the water produces a beautiful wreath of smoke as it rises in the air. The gas is produced by one part of the phosphorus taking hydrogen from the water, while the rest takes oxygen and combines with the potassa. As it burns, the hydrogen forms water with the oxygen of the air, and the phosphorus also unites with oxygen.

338. Take a stick of phosphorus, holding it with pincers, and draw lines with it upon a wooden board in a dark room; whenever the phosphorus touches the wood, a portion is absorbed, which retains its luminousness for a long time.

CHAPTER XIV.

CARBON, CARBONIC ACID, CARBONIC OXIDE, COAL AND OIL GAS, COMBUSTION, PREVENTION OF SMOKE, VENTILATION.

339. *Carbon* is the term applied to an element very abundantly distributed throughout the globe, and familiarly known in an impure form in the condition of charcoal, coke, lampblack, and soot. It is an infusible but combustible solid, burning freely when heated in contact with air, but remaining unchanged at all known temperatures when excluded from contact with the air and other substances. Carbon forms the principal part of coal, and also of all animal and vegetable substances. Its most important compounds are those which it forms with oxygen, hydrogen, and nitrogen, of which all animal and vegetable substances are principally composed, and in

which they are associated in an endless variety of proportions. Carbon is found in many different conditions, of which the following ought to be more particularly noticed:—

I. The *diamond* is composed of pure carbon.

II. *Charcoal* consists almost entirely of carbon, and is prepared by heating wood so as to expel all the gaseous matter it contains. Heat a few chips of wood in a glass tube by the flame of a lamp, or in an iron pot placed upon a common fire, so long as gas and vapour are rapidly disengaged; charcoal is left, which must be excluded from the air as it is cooled, to prevent it from taking fire.

III. Heat common coal in the same manner; coal gas and other compounds are expelled, and the carbon is left as a cinder, forming what is commonly termed *coke*.

IV. *Lamp-black* is the carbon deposited from a smoky flame.

V. *Ivory-black*, or *animal charcoal*, are terms usually applied to carbon in the condition in which it is obtained when bones are heated and the air excluded. A large portion of earthy matter is mixed with it in this condition, and in particular, a portion of lime uncombined with other matters, in addition to a large quantity of phosphate of lime. The uncombined lime is in many cases the cause of numerous peculiarities attributed in general to the carbon alone.

VI. *Plumbago*, commonly called *black lead*, is composed principally of carbon with a small quantity of iron.

VII. *Coal* consists in general of carbon, oxygen, hydrogen, and nitrogen, and is considered to have been formed from decayed vegetable matter. Few traces of animal matter have hitherto been observed. When heated, the gases are expelled, and carry along with them a quantity of carbon, producing common coal-gas, which burns upon the coal if air be supplied to it, but may be conveyed, as in gas-pipes, to any distance if the air be excluded. Other gases are also formed.

VIII. *Splint coal* has a splintery fracture.

IX. *Caking coal* fuses, and forms a cake when heated.

X. *Cherry coal* has a slaty fracture, and is easily broken.

XI. *Cannel coal*, or *parrot coal*, gives much gas when heated, and was formerly used instead of candles.

XII. *Glance coal*, or *anthracite*, consisting almost entirely of carbon, gives no gas when heated, but burns with a fixed light.

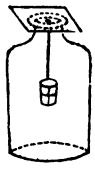
XIII. *Brown coal, bituminous wood*, or *surturbrand*, has a brown colour, and resembles peat.

XIV. *Jet* is another variety of coal; it is used in making black ornaments. *Naphtha, petroleum, mineral tar, mineral pitch, mineral caoutchouc*, and *fire damp*, are all composed prin-

cipally or entirely of carbon and hydrogen, and considered as products of the decomposition of coal; substances similar to most of them being formed in preparing coal-gas.

340. Put some fragments of charcoal in a copper cup or cage; heat any of them to redness in a lamp, and introduce them into a jar, flask, or phial, containing oxygen (fig. 40). A brilliant combustion takes place, the charcoal burning with a fixed light. Carbonic acid gas is always formed when carbon is freely supplied with oxygen, whatever its source may be.

Fig. 40.



341. In the combustion of a common fire, where there is a thick bed of cinders, three circumstances require attention:—

I. Carbonic acid is formed below where the air first acts upon the carbon.

II. Part of the carbon of the superincumbent red-hot cinders takes away half of the oxygen from the carbonic acid as it rises through them, and 2 particles of carbonic oxide gas are formed by the decomposition of every particle of carbonic acid.

III. The 2 particles of carbonic oxide burn with a blue flame as they come in contact with fresh air, producing 2 of carbonic acid, as an additional supply of oxygen is communicated to them.

These changes may be thus expressed symbolically:—

I. $C\&O^2 = :C$. Carbon and 2 of oxygen produce carbonic acid.

II. $:C\&C = 2{\cdot}C$. Carbonic acid and 2 of carbon produce 2 of carbonic oxide.

III. $2{\cdot}C\&O^2 = 2:C$. 2 of carbonic oxide and 2 of oxygen produce 2 of carbonic acid.

342. In the preceding symbolic arrangements, the action that ensues between pure oxygen and carbon has alone been represented; but this illustration being one of great practical importance, the precise nature of the changes as they ensue between carbon and oxygen, as it is associated with nitrogen in air, should be carefully studied as they are represented in the following lines:—

I. $C\&2{\cdot}N^2 = :C\&N^2$. 1 particle of carbon and 2 of air produce carbonic acid and 2 of nitrogen.

II. $:C\&C\&N^2 = 2{\cdot}C\&N^2$. Carbonic acid and carbon, and 2 of nitrogen, produce 2 of carbonic oxide and 2 of nitrogen. In this and in the succeeding stage of the process, it will be observed that the nitrogen, liberated at first from the air as represented in I., merely accompanies the other products without undergoing any change.

III. $2{\cdot}C\&N^2\&2{\cdot}N^2 = 2{:}C\&N^4$. 2 of carbonic oxide, and 2 of nitrogen, and 2 of air, produce 2 of carbonic acid and 4 of nitrogen.

343. In warm weather there is much moisture in the air, and the hydrogen of the watery-vapour which passes through the fire produces with the carbon a gas, which, as it burns, changes a little the colour of the blue flame. The blue flame is usually seen most distinctly in very cold frosty weather, when the air contains little moisture, and when the fire presents a thick bed of cinders.

CARBONIC ACID AND CARBONIC OXIDE GASES.

344. *Carbonic acid* consists of 2 particles of oxygen and 1 of carbon. *Symb.* :C. Prepare carbonic acid gas at the pneumatic trough, using the bottle and bent tube represented in fig. 28, introducing into it an ounce of aqueous hydrochloric acid previously mixed with 2 of water, and about a table-spoonful of large fragments of chalk or marble, which are composed of carbonic acid and lime; the hydrochloric acid unites with the lime, and carbonic acid gas escapes with effervescence. *Symb.* $HCl\&{:}C{\cdot}Ca = HCl{\cdot}Ca\&{:}C$. Two or three jars of gas may be collected, and a flask or bottle filled half full.

345. Introduce a lighted candle into one of the jars; it is immediately extinguished.

346. Invert another jar, and leave it without any cover for five or ten minutes; then try it with the candle as before: the carbonic acid gas being heavy, remains in the jar for a considerable time.

347. Shake the bottle with carbonic acid and water, the gas is absorbed. Add a little litmus in solution; the blue changes to a red. Boil a little of the red liquid in a flask or tube; the gas escapes, and the blue is restored.

348. Carbonic acid gas is fatal to animal life: animals introduced into it immediately die. Diluted with air to such an extent that respiration may be continued, it produces headache, oppression, dullness, and inactivity. It is evolved by the combustion of carbon, and by respiration; so that crowded or ill-ventilated apartments are extremely unwholesome, and sometimes dangerous, from the accumulation of carbonic acid. It is found during fermentation and putrefaction, and accumulates in old wells, pits, and caverns: before attempting to enter into any of them, a lighted oil-lamp should be introduced, and if extinguished, any one entering would probably be suffocated. A candle is often extinguished in air vitiated with carbonic acid, though a lamp may burn in it, and gas burns for a short

time in air so contaminated that neither a candle nor an oil-lamp can burn in it.

349. *Carbonic oxide. Symb.* ·C. This is the gas that burns with a lambent blue flame on the top of a cinder fire. It may be procured most conveniently for experimental purposes in the following manner:—

350. Heat 50 grains of crystallised oxalic acid in a retort with an ounce by measure of aqueous sulphuric acid. Collect the gases evolved at the pneumatic trough. The oxalic acid is decomposed and resolved into carbonic acid and carbonic oxide gases, as the hot sulphuric acid removes its water of crystallisation. *Symb.* :C^2=:C&·C.

351. Invert a jar of the mixed gases, and pour into it as much lime-water as will fill it about one-third full. Shake the lime-water with the gases, keeping on the cover of the jar; carbonic acid gas is condensed, producing carbonate of lime, which renders the liquid milky. Inflame the remaining carbonic oxide; it burns with a blue flame.

COAL AND OIL GASES.

352. When coal, oil, tallow, wax, resin, and many other inflammable substances, are exposed to heat, gaseous compounds of hydrogen and carbon are produced in large quantity. In an open fire, the gas burns as it escapes from the coal, &c.; and an oil-lamp or tallow candle may be compared to a small gas manufactory, where the gas is consumed by the air as it is produced upon the wick.

353. Heat by a lamp some fragments of coal in a small test tube; gas is expelled, which may be inflamed. Water charged with ammonia and a tarry matter may also be seen as the heat is continued; coke is left in the tube.

354. When coal contains sulphuret of iron, hydrosulphuric acid gas is also formed, which is removed by lime. Ammonia is condensed by acids; and sometimes, instead of the more common acids, fatty matters are employed, many of which are regarded as peculiar acids.

355. The gaseous compounds of hydrogen and carbon are usually called *carburetted hydrogen gases.* The more they abound in carbon, the richer the flame they produce as they burn. *Hydruret of carbon* is more valuable than the *bihydruret*, and is found in larger quantity in oil than in coal gas. Their composition may be seen in the table, page 23.

356. The products of the combustion of carburetted hydrogen gases are carbonic acid and water, the nitrogen of the air being separated.

357. Hydruret of carbon acts on 3 particles of air; carbonic acid and water are formed, and 6 of nitrogen separated. *Symb.* $HC\&3{\cdot}N^2 = :C\&{\cdot}H\&6N$.

358. Bihydruret of carbon consumes 4 particles of air, producing 1 of carbonic acid and 2 of water, 8 of nitrogen being detached. *Symb.* $H^2C\&4{\cdot}N^2 = :C\&2{\cdot}H$ and 8N.

359. The flame of a common lamp or candle is produced by the gas formed around the wick acting upon the oxygen of the air; it is confined solely to the exterior portion of the ascending gas. In fig. 41, *a a* denotes the part in a state of combustion. All without is merely heated air, or the products of combustion; and all within is unconsumed gas, rising in its turn to affect the oxygen of the air.

Fig. 41.

360. If a glass tube be introduced within the flame of a large lamp or candle, in the manner represented in fig. 42, part of the unconsumed gas passes through it, and may be kindled as it escapes. With a tube 1-4th of an inch in diameter, and a foot long, this is very easily shown; the wider the tube the better, if the flame be sufficiently large.

Fig. 42.

Fig. 43.

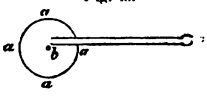
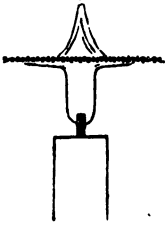


Fig. 44.

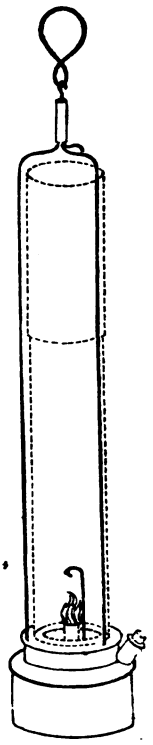


361. Fig. 43 shows a section across the flame, with the position of the tube.

362. The nature of flame is beautifully illustrated by holding over the flame of a candle, or of a large stream of gas, a piece of wire gauze 6 or 8 inches square, with about 1000 meshes in the square inch. The flame is intercepted, and appears only below the gauze, a tube of flame appearing expanded as it reaches the gauze. The unconsumed gas rises through the gauze, and if a lighted match be applied, it burns on the upper side; the appearance is then presented, as seen in fig. 44.

363. A white heat is required to cause the combustion of common gaseous matter in most cases with flame, and an intense heat is equally produced by the combustion of gas with flame. If flame be produced on one side of wire-gauze with small apertures, the metallic wires of the gauze being always kept cold by the surrounding air, any burning gaseous matter coming in contact with it is so much cooled, that it soon ceases to burn, and is incapable of inflaming unconsumed gas on the other side, after it shall have passed the gauze.

Fig. 45.



364. Fig. 45 represents the miner's safety-lamp, invented by Sir H. Davy, where a common lamp is surrounded with wire-gauze. In coal-mines, the atmosphere frequently becomes explosive, from the large quantity of bihydruret of carbon, the *fire-damp* of miners, which escapes from the coal as it is worked, and a lighted candle would instantly detonate the mixture. But with this lamp, though the explosive mixture may enter within the gauze and burn there, the flame within cannot set fire to the explosive mixture without, so that the miner has time to escape. If the current be strong, however, and the wire much heated at any one point by the flame being directed continually upon it, then it is apt to pass through the gauze, and set fire to the explosive mixture in the mines.

365. The intensity of light produced during the combustion of any gaseous matter, depends much upon the manner in which the gas is consumed. In producing a highly luminous flame, attention should be paid to the following circumstances:—

I. The combustion must be made to take place in such a manner that an intense heat is produced.

II. The gas, as yet unconsumed, is decomposed by the heat, and much solid charcoal is separated and suspended in the flame for an instant.

III. This charcoal must be intensely heated, so as to be consumed. Any unconsumed charcoal gives a yellowish tinge to the flame, and, if in large quantity, is deposited ultimately in the form of soot.

366. In an argand burner, fig. 46, the intensity of the heat

is augmented by causing air to enter in the middle of a circular wick or series of gas jets, so that more gas is consumed within a given space than in the ordinary manner. Thus, in fig. 47, a section of the argand burner fig. 46, it will be seen that the surfaces of the burning gas *aa*, *aa*, are very near, so that the interposed gas is heated much more than when these surfaces *aa* are distant, fig. 48. Much carbon, therefore, is precipitated, and becomes intensely luminous before it is consumed.

Fig. 46.

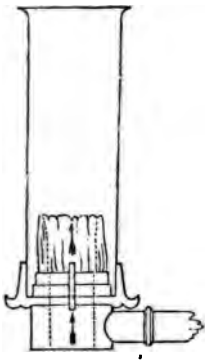
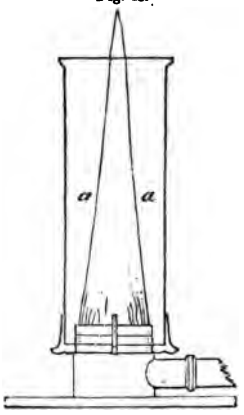


Fig. 47.

Fig. 48.



367. If the aperture by which air is admitted into the interior of the flame be closed by a piece of paper, the flame represented in fig. 46 immediately assumes the form shown in fig. 48; part of the supply of air being cut off, it extends farther into the air before it meets with the oxygen necessary for combustion. The heat is accordingly diffused over a larger surface, and becomes less intense; *a* and *a* are more distant from each other; a smaller quantity of carbon is deposited, less gas being decomposed, and even that which is separated being less intensely heated, much of it is unconsumed, and produces a dingy and imperfect flame.

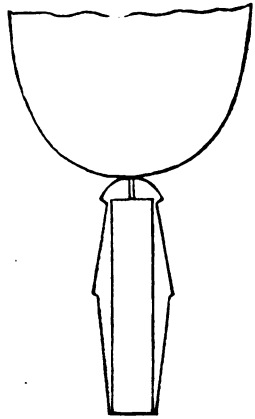
368. The most perfect form of burner is seen in the flat gas jet, fig. 49, where two opposing currents of gas meeting each other, flash into an extremely thin sheet of gas, which extends in an opposite direction to the currents which produce it. Fig. 50 is a section of the same jet, the side of the flame being turned towards the eye. Here, the gas on one side being so extremely

near that on the other, all the conditions are fulfilled which are necessary for intense heat and light.

369. In the bat-wing burner, a similar but less perfect combustion is induced by causing the gas to issue from an open slit in the head of the burner.

Fig. 49.

Fig. 50.



370. For some purposes where gas is used, it escapes with too much force to be employed conveniently, as in experiments with the blowpipe. By placing over it a small brass tube, fig. 51, covered with wire gauze, a better flame for this purpose is procured.

Fig. 51.

Fig. 52.

371. If air be mixed with gas before it is inflamed, as by allowing it to rise in a tin chimney, to which the air has free access on every side, wire-gauze being placed over the top of the chimney, a flame is produced which is not more luminous than that of a spirit of wine lamp, and produces no smoke. Fig. 52 illustrates the arrangement adopted. It is easy in this way to procure a flame from an inch to a foot in diameter. Burners of this kind have been much used of late for the steady application of heat, both for domestic purposes and in the laboratory of the chemist.

372. Fig. 53 represents the roasting burner, in the manner it is manufactured by Mr Milne of this city; it consists of a

circular tube, from which numerous jets of gas escape, the meat being placed upon the upright spit in the centre.

FURNACES, FIRE-PLACES, VENTILATION.

373. If a fire be kindled in the middle of a room (fig. 54), the door, windows, and chimney, being completely closed, the air at the fire-place expands, and becomes lighter, bulk for bulk, than the rest, which descends and flows under it, pushing it upwards in the same manner as water poured into any vessel with a cork at the bottom, sinks under the cork, and floats it as it insinuates itself below it. A perpetual circulation thus goes on so long as the heat is continued, all the air being in time involved in this movement, cooling and sinking on the exterior, while fresh quantities are continually expanding as the heat affects them.

Fig. 53.

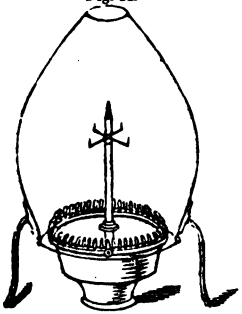
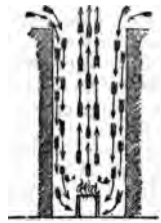


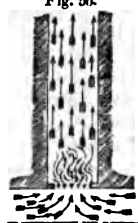
Fig. 54.

Fig. 55.



374. If a fire be kindled in an apartment or chimney, close below but open above, a current of warm air ascends, the cold air descending at the sides and forcing it up, so that the air is continually renewed; see fig. 55.

Fig. 56.



375. When a fire is heated in a chimney open below and above, the air moves quickly, the warm air in the chimney being pushed up rapidly by the external cold and heavier air, fig. 56.

376. When two chimneys are connected together by a flue (fig. 57), and a fire kindled in one of them, the air ascends in the one with the fire, being pushed upwards by the cold air which descends through the other. A similar arrangement is

adopted in ventilating numerous mines; the horizontal part of the figure may represent that part of the mine which is worked, and the perpendicular portions the two shafts which lead to the mine, the air descending in one and rising in the other.

Fig. 57.

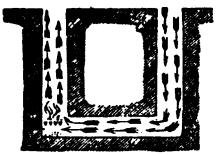


Fig. 58.

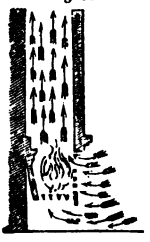


Fig. 59.

377. In fig. 58 the currents are represented as they occur in a common fire-place. Air enters by the doors or windows.

378. Fig. 59 illustrates the currents in a furnace. There, the space left open in a common fire-place being closed, a more intense heat is produced, as no air escapes into the chimney which does not pass through the fuel and contribute to the combustion.

379. Wherever air continues to escape, fresh air must have free access to the apartment. When the doors and windows fit so tightly as not to admit of this, then some aperture must be made for this purpose alone. Fig. 60 represents a mode which has been occasionally adopted for this purpose, one chimney leading in a descending current of fresh air, while by the common chimney it is carried away.

Fig. 60.

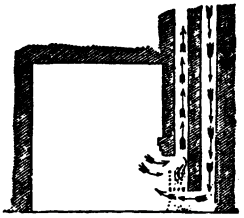
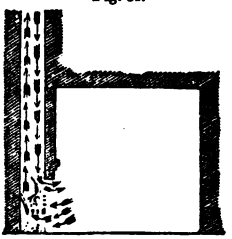


Fig. 61.



380. When air is not admitted by this or some other arrangement, cold air descends in the chimney, entangling and carrying down some of the ascending warm and smoky air, and in

such cases the room necessarily smokes; two currents, accordingly, an ascending and a descending current, perpetually affecting and interrupting each other, may be seen in all such vents. (See fig. 61.)

THE OPEN FIRE.

381. The general nature of the open fire-place will be sufficiently understood from the preceding illustrations. When properly supplied with air, there is no return of smoke, and the warmth it affords depends solely upon the heat which it radiates, unless it be conjoined with arrangements such as give it in some respects the character of a stove. This combination is not uncommon, the open fire being sustained in an iron frame, from which the consumed air is carried away by an iron pipe or tube traversing the apartment to be warmed, and communicating, accordingly, a considerable amount of heat, which, under other circumstances, would have passed away by the chimney.

382. Independently of the cheerful appearance presented by the open fire, it is distinguished by the purity of the heat it affords, and the constant circulation of air it maintains in the apartment in which it is placed. The less the quantity of metal, the greater the heat projected into the room. With large metallic bars and plates a great quantity of heat is continually withdrawn by conduction, as the air which passes by them ascends in the chimney. Sometimes polished brass plates are used with advantage at the sides of particular fire-places, to reflect into the apartment any radiant heat which may fall upon them. Grates are almost invariably placed too high: branders supporting the fire should be on a level with the floor, and the ash-pit sunk below it.

383. The term draught is usually employed in reference to chimneys; and when air passes through them quickly, they are said to draw well. The movement begins with the expansion of the air in contact with the burning fuel, and the farther movement of the air depends upon the colder and heavier air meeting with less resistance than before from the expanded and lighter air in the chimney; and the greater the difference between the specific gravity of the external air and that in the chimney, the more rapidly does the movement go on, or, in common language, the better does the furnace draw.

384. If the smoke from a common fire be not carried up the chimney, and if there be sufficient air allowed to enter by the doors or windows, then, by closing the aperture between the top of the fire and the chimney, so that no air can have access

to it except through the fuel, the smoke may in general be prevented from returning, for, by excluding the entrance of cold air above the fuel, the gaseous products in the vents are maintained at a higher temperature, and have consequently a greater ascending power.

385. The *smoking of a fire* may arise from a great variety of causes, among which may be more particularly enumerated:—

386. I. Interruption to the discharge, arising from too small a vent, or from the action of a current of air striking with force upon the chimney top. A moveable cowl which turns with the wind, often affords the best protection in such cases. Where the vent terminates below a high wall, from which the wind is reflected back upon it, producing a return of smoke, it is often necessary to carry the vent above the wall, that it may be beyond the influence of such currents.

387. II. The operation of currents in other apartments more or less distant. For example, if the external doors and windows of a house be so closely fitted that little or no air can enter by them, and if they should all be closed at the same time, while a large and powerful fire is maintained in any one apartment, as in the kitchen, it is obvious that air must descend through the smaller chimneys, even though fires be kindled in the fire-places connected with them, the great ascending power produced by the large fire in the kitchen overcoming all the minor draughts in the other apartments, and drawing air down through them, which, after producing an offensive smoke in them, and finding its way through the passages, arrives at the kitchen. The obvious remedy in this case is to admit air freely to the passages or to all the individual apartments.

388. It cannot be too particularly remembered, that air in contiguous apartments may be compared to materials poised with the most scrupulous care in the most delicate and sensible balance, and that air within any apartment stands in the same relation to the external air, other circumstances being the same. When, from expansion induced by heat, or any mechanical impetus produced by the wind or any other cause, an increase of pressure is induced at one place, or a diminution at another, a movement in the air is the necessary consequence, and this ensues as certainly as a disturbance in the equilibrium of the pans of a nicely adjusted balance, when an increased weight is communicated to one, or a portion removed from the other.

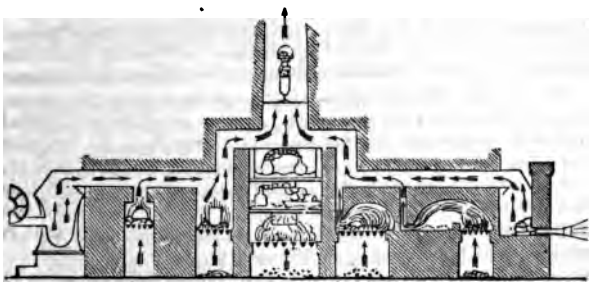
389. Again, though smoke and heated air always tend to ascend, they may in numerous cases be very advantageously forced to take a descending movement in the first instance, where particular circumstances render it desirable that the surface of the fuel should be exposed, or when an ascending

flue cannot be conveniently procured. In all arrangements of this kind a large flue or chimney is provided at first, in which all the smaller descending branches are made to terminate; and the air in it being heated, it draws downwards, horizontally, upwards, or at any inclination, the air from all the apertures, and through all the branches that lead into it, provided it be sufficiently large.

390. It would be a great security against fire, and ensure a much more agreeable atmosphere, if all houses, whatever might be the number of apartments, were provided with one large chimney alone, all others leading into it. It would not then be difficult to prevent smoke in any ordinary atmosphere, the ascending movement from all the chimneys producing great strength in the current, so that it would resist any sudden gust of wind, such as would blow down any individual branch or small chimney, if left alone to contend against it. Some buildings are now in progress where numerous apartments are to be provided with flues according to this arrangement.

391. The two following figures illustrate the general arrangements adopted where many flues terminate in one large shaft or chimney, and should be studied carefully till the movement of the air in each individual compartment shall be distinctly understood; they represent some of the principal flues and furnaces attached to the large chimney in the centre of a chemical class-room, and the manner in which they enter in on every side, above and below ground; the arrows point out the course which the different currents take till they reach the

Fig. 62.

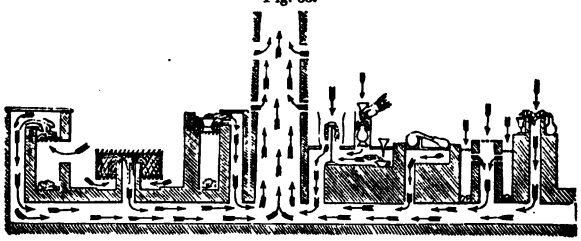


central chimney. In some extensive manufacturing establishments, from 100 to 200 furnaces often play into a single chimney, which may be seen occasionally at some distance, and rising alone in an adjoining field, underground flues conveying

all the smoke to it. Such chimneys are often carried to a great altitude, in order to remove noxious fumes to a distance.

392. To the right, in fig. 62, a *smith's forge* is first observed; then a *reverberatory furnace*, where the flame dashes over the material to be heated; and then another furnace for miscellaneous operations. Below, and in the middle, a furnace is placed to heat the superincumbent iron sand-bath plate, evaporating basins being put there, while noxious fumes are carried away by the aperture represented. Above is another plate of a similar form, from which a more moderate heat is procured. A glass is also represented resting on a projection, and before an aperture in the chimney, so that offensive gases from it are rapidly withdrawn. To the left, the first furnace observed is used for operations where an intense heat is required; the large open space above the fuel allows all the consumed air to escape with rapidity, and fresh air to enter. A furnace, with an earthen vessel called a *muffle*, is next seen; it is used in refining gold and silver. A blast furnace for melting iron is observed at the extreme left; the air, instead of entering through furnace bars, being propelled by a fanner turned two thousand times a minute by a steam-engine.

Fig. 63.



393. In fig. 63 the other section of the same chimney is shown, illustrative of the arrangements adopted in several of the furnaces with descending flues, and of the manner in which fumes are carried off in numerous operations where the phenomena could not otherwise be so easily shown, without injury to the operator and those around him.

394. On the extreme right four apertures are seen for this purpose, which are used with different kinds of apparatus. The retort which follows rests upon a few cinders mixed with charcoal, the air descending as in the other flues, while the receiver *is kept cold by* the rapid current of air descending on every *side. In the next* figure the experimenter is supposed to be *introducing antimony* or arsenic into a vase of chlorine gas-

STOVES.*

397. The stove is very different in many respects from the open fire, but more particularly from the circumstance that heat is communicated by it to the surrounding air largely by conduction, as the air comes in contact with it, independently of that portion which is radiated, whatever its temperature may be above that of the contiguous atmosphere.

398. Stoves are usually made of earthenware or of iron. The latter is generally preferred in this country, and iron stoves may be divided into different classes, according to the temperature to which the air in contact with them is exposed. The higher the temperature of the stove, the less pleasing is the quality of the air that comes in contact with it. Minute particles of dust or of any other substances are often scorched and rendered offensive by it, while in extreme cases a portion of the oxygen of the air must be removed; the more intense the heat, the less is the amount of heating surface necessary, but when stoves are heated to redness, the air proceeding from them is apt to ascend at once to the ceiling of the apartment into which it is introduced, and to remain stationary there, while a comparatively cold atmosphere is observed below. The great object at all times should be to construct a stove with a very extensive heating surface, and to cause it to operate upon air before it enters the apartment to be heated, so that the great mass of heat it communicates may be delivered on the floor. If the lower stratum of air be warmed, that above is certain to be warm also; but the air may be very warm above, without any sensible warmth being communicated to that portion which is below, and which comes in contact with the person.

399. Stoves are made of the form represented in fig. 65 in many parts of northern Europe, especially in Sweden, Russia, and Prussia. The fire rises to the top of the large apparatus employed, which is commonly made of earthenware: it then descends on one side, rises again on the same side, and passes to the other, where it descends and ascends as at first, after which it proceeds to the chimney. Fig. 66 indicates the various turns in the flues; and in fig. 67 a ground plan is given, the letters ABCDEF showing successively those communications through which the consumed air and smoke pass in the interior before the principal part of the heat is exhausted, after which they escape to the external air. A damper regulates the supply and

* For a description of hot-water apparatus, see "Communication of Heat."

escape of consumed air. A large surface is thus exposed to a very moderate degree of heat, and gives with great economy a mild and agreeable temperature.

Fig. 66.

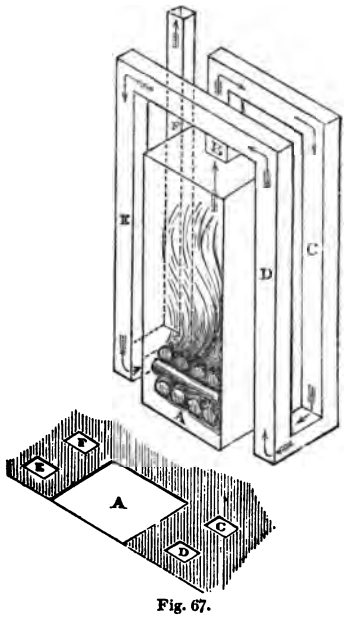
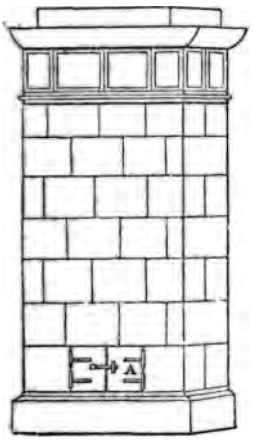


Fig. 67.

Fig. 65.



400. In many stoves, and more particularly in those in which air is warmed at a distance from the apartment to which it is to be conveyed, the heated air is produced by allowing cold air to enter between the inner case containing the fuel and an outer case; the air is warmed as it passes, and may be conveyed by pipes to a distant apartment. The smoke is led into a chimney by a separate tube. (See fig. 68.)

401. Dr Arnott estimates that three-fourths of the heat produced in a common fire-place is wasted or carried away by the chimney, and has proposed to employ an earthenware furnace enclosed in an iron box, so that a much larger portion of heat shall be obtained from the fuel, apertures being made in the iron chamber to regulate the currents of air. A great saving

of fuel has been effected in this manner. Fig. 69 shows the general arrangement. Numerous stoves have been constructed in this manner; and where the air is admitted with sufficient

Fig 68.

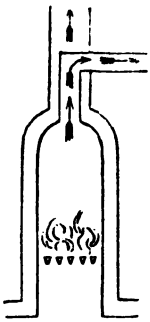
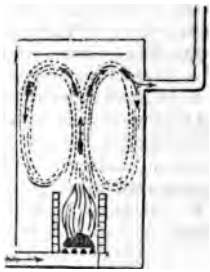


Fig. 69.



freedom at first, so as to produce carbonic acid, while the products of combustion are conveyed to a chimney where the draft is sure and certain, they are found to work well and prove very economical. If, however, the chamber for the fuel be overloaded, and the supply of air much too limited, carbonic oxide gas is apt to be generated, and in some cases even to explode, as it mingles with the air. Coke alone, or anthracite, can be used in these stoves.

402. Again, in stoves where the heat is exhausted to so great an extent from the products of combustion, the ascending power in the chimney is small, and a returning draught is apt to take place, unless great attention be paid to the state of the currents.

403. It will also be observed that they do not ventilate or change a large amount of air, as in the common fire. Ventilation, accordingly, where they are used, must be provided by independent means.

404. The most certain method of providing securely against the evolution of noxious gases where such stoves are used, consists in arranging them so that they shall be absolutely air-tight within the apartment in which they are, the fresh air being introduced into the stove by an iron pipe from without, in the same manner as the chimney is attached for removing foul air.

FURNACES.

405. In all cases where a strong heat is required, all apertures leading into the chimney above the place where the fuel rests

ought to be closed; and any of the apertures leading into the chimney from any furnace not in use, must also be shut, otherwise cold air rushing in by them reduces the temperature of the warm ascending current, and consequently reduces also the temperature in those furnaces in use, by preventing so rapid a consumption of the fuel. The general arrangements adopted in furnaces contrasted with those required in the open fire, are shown in figs. 58, 59, page 82.

406. If a single furnace be required, perhaps none will be found more generally useful than that represented in figs. 22 and 23. Another form is sometimes adopted (fig. 70), where it is not necessary to adapt it for iron bottles with attached tubes for the preparation of oxygen and other gases; if the flue be carried from 10 to 20 feet high, or be led into another chimney, it produces great heat. The numbers express the size in inches.

Fig. 70.

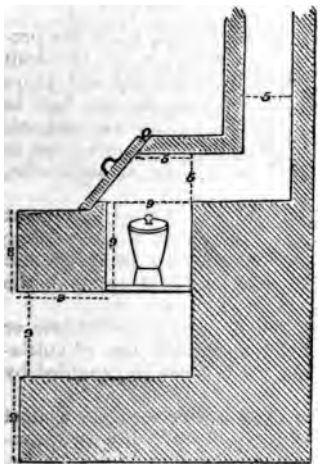
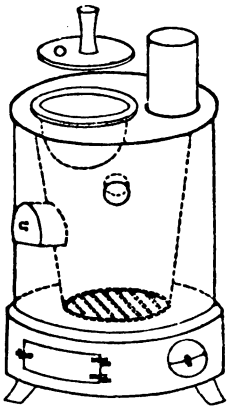


Fig. 71.



407. Dr Black's portable furnace (fig. 71) is much used, and consists of a case of stout sheet-iron lined to the thickness of 2 or 3 inches with a very infusible clay or earthy composition. Above is an aperture for an iron pot to contain sand, and other openings may also be observed for introducing tubes and different kinds of apparatus. The pipe carrying away the smoke must be prolonged, or connected with a chimney.

408. All furnaces where a steady and regulated temperature is required, must be provided with ash-pit doors, by which a fixed and steady supply of air can be admitted, and regulated so as to produce a powerful or moderate heat. By cutting off altogether the supply of air, the combustion of the fuel may be entirely arrested.

409. Where many furnaces play into one chimney, if it be not sufficiently large, only part of them ought to be used at the same time.

410. Besides those furnaces in which the supply of air is maintained by a chimney, there are numerous varieties where the combustion is supported by the action of air propelled by a powerful bellows or some other mechanical power. The smith's forge affords the most familiar example of this kind of furnace. The cupola is another modification much used in melting iron. In the smelting furnace, which is used on the large scale in reducing iron and other metals from their ores, a powerful engine is employed to force in the large supply of air required, in cases where upwards of a hundred tons of materials may be often observed at a red heat at the same time.

411. Small portable furnaces, called *chauffers*, are found very convenient in numerous operations where heat is required; they may be made from 3 to 6 or 8 inches in diameter, and 6, 8, or 10 inches deep. A chimney put over them increases the heat (fig. 72.) Tubes are often heated with them in the manner shown in figs. 73 and 74. Occasionally small crucibles are perforated and used as chauffers (fig. 75.)

Fig. 72.

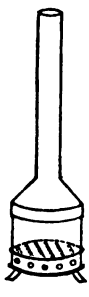


Fig. 74.

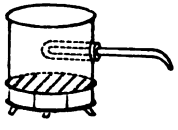
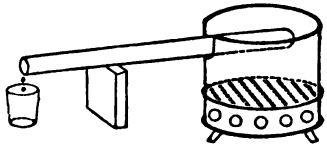


Fig. 75.

Fig. 73.

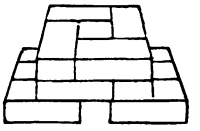


412. Chauffers are usually filled with red-hot cinders or charcoal. Wood heated in a common fire till all flame ceases,

gives excellent charcoal for this purpose. When the chauffer is very small, charcoal alone is employed.

413. With 20 or 24 bricks, and a few small slips of narrow hoop iron, a chauffer or small furnace may be constructed in a few minutes, capable of giving a good red heat, where the usual facilities for operating are not to be obtained, and where a common fire is not accessible. Suppose the bricks to be 5 inches broad and 10 long, 3 are laid side by side as in fig. 76, and 3 more in the same way, and opposite to the first, at the distance of 4 inches. The slips of iron are placed in the middle to support the fuel, and one or two courses of bricks laid above them, so as to leave an aperture 5 inches square. If the bricks be laid with mortar or clay, the current of air will be still stronger, and the heat greater. By using small pieces of charcoal, the heat may be moderated so as to be employed with flasks and retorts, as well as crucibles.

Fig. 76.



PREVENTION OF SMOKE.

414. In ordinary apartments, the prevention of smoke signifies rather the actual discharge of such smoke as may be produced in the fire-place by the chimney, than the regulation of the process of combustion in such a manner as to avoid in a great measure, if not altogether, its production. This discharge may be secured by attending to the illustrations given in the description of fire-places, stoves, &c., and in the succeeding paragraphs on ventilation. The remarks in the following paragraphs apply to different points not included in other chapters, but which require minute attention where it is a great object to prevent the production of smoke.

415. In the common fire-place, the amount of smoke produced may be diminished by regulating the amount of fuel with greater care than is generally taken, supplying it at more frequent intervals when particular kinds of coal are used which do not allow a large charge to be consumed slowly and equally, and by arranging it so that the air shall have free access to the smoke and gas as they are evolved; should they become cold before they mingle with the air, it is impossible to ensure their combustion by any convenient process.

416. When fresh coal is placed on a very warm fire in full combustion, it removes much heat from it in the first instance, that heat being consumed in producing gas and expelling the various matters that are discharged either in this condition, or

mechanically suspended in the gases. The word smoke, therefore, indicates an ever-varying mixture, in which the following substances more particularly may be traced:—

I. Bituminous matter mechanically suspended in the gaseous products, containing numerous oily and resinous compounds.

II. Carbon also mechanically suspended, and produced principally by deposition from part of the carbureted hydrogen gases decomposed by the heat to which they are subjected.

III. Unconsumed carbureted hydrogen gases. Those portions that are consumed produce flame.

IV. Carbonic acid gas, formed by the carbon and the oxygen of the air.

V. Carbonic oxide gas, formed by the imperfect combustion of part of the carbon.

VI. Nitrogen gas from the air.

VII. Unconsumed oxygen in variable proportion.

VIII. Watery vapour, produced by the hydrogen of the coal and oxygen of the air.

IX. Ammonia, a compound of nitrogen and hydrogen, formed as the coal is decomposed.

X. Sulphurous acid gas, formed by the combustion of sulphur in the coal with the oxygen of the air.

417. Few subjects have attracted more attention of late than the means of preventing smoke in ordinary houses, as well as in manufacturing operations. The reduction of the nuisance from smoke, the economy of fuel, and the prevention of fires in chimneys prone to accumulate soot, have all been the subject of minute practical attention. In many places the introduction of soft coke for open fireplaces, and the use of anthracite in manufactories, has superseded the necessity of further attention to this question, in so far as it has prevented the production of visible smoke. But in the majority of cases the evil is still perhaps most ineffectually controlled, or rather not made the subject of special attention, notwithstanding the resources which numerous inventions have brought to bear on this point. These consist principally in arrangements for the more equal and continuous supply of small portions of fuel to large fireplaces, and of the introduction of air at such places, and with such distribution, as shall consume the fuel as equally as possible, aided in some cases by the action of steam, or of a rotatory or revolving motion communicated to the furnace bars.

418. In manufactories, the combustion of the carbonaceous and other inflammable matters in smoke is not always desirable, a deoxidating power being required, which is essential in *some operations*. In all other cases, the more perfect the com-

bustion, the greater the amount of heat produced from the fuel used.

419. When the gaseous products discharged from any fire or furnace are invisible, the combustion may in general be presumed to be complete; this is not always a correct conclusion, however, as the invisible carbonic oxide is often evolved, indicating, where it can be detected, a deficiency in the supply of air.

420. Steam applied to carbon or smoke evolved by imperfect combustion, is decomposed when it approaches them at a sufficient temperature, forming with the carbon the invisible carbonic oxide and carbureted hydrogen gases; unless these meet with abundance of air, and be sufficiently heated, they are not consumed.

VENTILATION.

421. The process of ventilation consists in the renewal of air in any apartment, so as to ensure the expulsion of all offensive products developed by respiration, combustion, or in any other way, and particularly carbonic acid, watery vapour, and effluviæ evolved either from animal or vegetable substances, or produced by chemical or other operations in buildings applied to manufacturing purposes, in mines, or any situation where the most free, direct, and open communication does not exist between it and the external air.

422. In the great theatre of the globe itself, natural ventilation is sustained by the varied currents induced in the atmosphere, which not only tend to prevent stagnation in any individual place, but also to maintain a great movement continually in operation, by which the warmer air of the equatorial regions is conveyed to the temperate and polar regions, while they return a denser and colder atmosphere, which is again heated and circulated in the same manner as before. This vast movement in the atmospheric ocean is not supposed to be determined solely for the purpose of moderating the extremes of heat and cold, see par. 181, but it has also been considered that the luxuriant vegetation in the brilliant sunshine of warmer climes produces generally a purer air, and, in particular, absorbs much of the carbon of the carbonic acid which is found in minute quantity in the air in every part of the globe, and evolves oxygen in its place; thus giving to the temperate and polar regions a purer atmosphere than they would otherwise possess.

423. In the process of ventilation, the principal points that demand attention are the following:—The ingress and egress of air, and the nature of the moving power; the amount of

supply required; the source from which the air ought to be taken; the filtration and purification of the air; the warming or cooling of the air; drying and moistening; the degree of diffusion that may be required; the discharge of the vitiated air; and the exclusion of all offensive products from drains or other sources which might be liable to injure the usual source of supply.

424. In all ordinary cases, the movement in the air required for ventilation may be sufficiently developed by natural causes, if one opening sufficiently ample be left for the ingress of air, and another of the same size be provided for its exit; a mechanical power may be used in particular situations, but the heat of the body, of lamps, candles, coal gas, fire-places, and furnaces, when in full operation, will be found sufficient, under all ordinary circumstances, to command the required movement. Mistakes productive of the most injurious consequences arise in general from the imperfect arrangements of the moving power, and from the supply of air being totally inadequate in numerous cases where many persons are crowded together in public assemblies. In extreme cases, where many people crowd closely upon each other, it has been found that there is in general one man upon each square foot, or two boys, the average age of the latter varying from seven to fourteen. It is rarely, however, that such dense crowds are observed, except upon a very limited area.

425. The air ought not to be taken from the surface of the ground, especially in damp situations or in cities, as the air there is often loaded with foul exhalations. Neither ought it to be taken in at the level of the chimney tops in streets, nor at any particular height where the opening by which it may have to enter is on a level with any other from which offensive fumes are evolved.

426. The amount of air required for each respiration may be estimated at twenty-two cubic inches for an adult; but as it is expired, it mixes with and contaminates so much of the contiguous air in confined apartments, that twenty cubic feet per minute are not considered too large a supply in warm weather. The higher the temperature, and the more largely the air is charged with moisture or any other extraneous matter, the more is required for respiration. Damp air arrests insensible perspiration; very dry air promotes it, and feels offensive from the rapidity with which it absorbs moisture. In winter, in situations where not more than one or two cubic feet per minute are given to each individual, ten, fifty, and one hundred, are frequently given with advantage in summer. Were the expense of warming, moistening, and drying the air not

considerable, it would be proper to give a much larger supply in numerous cases than is generally allowed. In the same individual, also, great diversity is observed in the amount of the air that is most agreeable, not only from the state of the external atmosphere, but also according to the condition of the system, the nature of the temperament, the occupation that may principally engage attention, and the period at which any refreshment may have been taken.

427. In numerous situations, more especially in populous cities, and in the vicinity of certain manufactories, or where particular natural impurities may be observed, much may be done, by filtration through cloths, to purify the air from impurities mechanically suspended in it, to condense sulphurous and other acids by lime-water, and to destroy peculiar contagious or other deleterious ingredients by the action of heat, acids, chlorine, and other chemical agents.

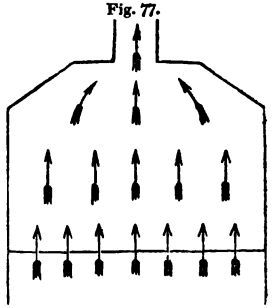
428. In warming air, the great object should be to heat the whole of the air in any apartment moderately, and to avoid local currents as much as possible. Air may be obtained comparatively cool by providing various apertures from which it may be taken, according to the circumstances of the moment; if these be placed so that air can always be taken from the shaded side of a house, and also cooled by the evaporation of water, spread out upon an extensive surface in vaults which the sun never penetrates, a very considerable reduction of temperature may be secured.

429. Moisture is communicated with facility to the air by the evaporation of water. It is required more particularly when cold air that has previously deposited its moisture is subjected to the action of heat. Lime is much employed in particular places for drying air; a few lime-shells placed in a damp apartment will in many cases remove moisture so freely, that it may be occupied without those injurious consequences which it is otherwise apt to induce.

430. Air cannot be admitted by too many apertures in crowded assemblies, or even in private dwelling-houses. When it is admitted by one or a few apertures only, it produces local currents such as have been so frequently referred to in the preceding chapters. In some apartments lately built, the walls and floor have been constructed of porous materials, so as to give the greatest diffusion possible, and, consequently, the opportunity of introducing large supplies of air with the least possible impetus. In class-rooms, churches, and other places where fixed benches are constructed for each seat, each individual may be supplied with fresh air for his own consumption, instead of respiring that which in numerous cases has in part been

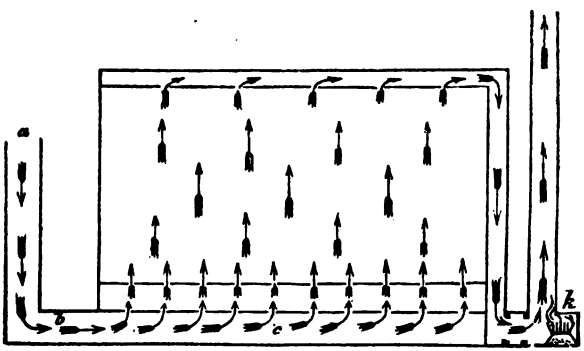
respired previously by other persons. The diagram shows the general progress of the air in a public hall supplied from the floor alone, the air escaping throughout its whole extent from an air-chamber immediately below the floor, in which it can be heated to any temperature that may be required. The warmer the air, and the smaller the apertures by which it is admitted, the greater the amount that can be introduced in a given time without producing an offensive impetus on the person.

Fig. 77.



431. The diffusion of the air introduced forms one of the most important features of systematic ventilation, and becomes more and more imperative according to the crowded state of the apartments to be ventilated. Fig. 78 illustrates the general arrangements introduced for the ventilation of the present House of Commons, those that prevent the ingress of dust not being represented; 50,000 cubic feet per minute are frequently given in this house in very sultry and oppressive weather. The air in the chimney having been heated powerfully and expanded much by the furnace *k*, cannot oppose the colder air in the apartment, which accordingly presses it upwards, and is forced in the same course in its turn: fresh air accordingly descends at *a*, and passes by *b*, *c*, through the aper-

Fig. 78.



tures in the floor, rising in a slow but constant stream to the roof, whence it is conveyed to the chimney. Valves are placed so as to allow the rapidity of the current to be regulated according to the quantity of air required. A power is thus obtained capable of operating to any extent, and so completely under control that it can be adapted to the varying circumstances in which it may be applied, while it can also be easily regulated, and diminished or increased in an instant with the utmost precision. It acts upon air whether it may have previously been heated or cooled within the whole ranges of temperature observed at the surface of the earth, where no unusual circumstances present themselves.

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432. Selenium and boron are similar in their general chemical relations to sulphur, phosphorus, and carbon, but are not so important, and require accordingly only a short notice in this place.

433. *Selenium* is a dark-brown solid, having a semi-metallic lustre. It is insoluble in water, inodorous, and produces a strong smell of horse-radish when heated in contact with the air. *Symb.* Se—Equiv. 40.

434. *Boron* is an element which resembles carbon in appearance and properties. *Symb.* B—Equiv. 11? Its most important compound is *boracic acid*, which is a compound of boron and oxygen. *Symb.* ⁝B—Equiv. 35.

435. Boracic acid is a white solid, and is fused by heat. It is soluble in water and alcohol, and its alcoholic solution burns with a green flame. It is obtained by the action of sulphuric acid upon borax, which is a biborate of soda. The borax is dissolved in four times its weight of boiling water, and sulphuric acid diluted with four times its weight of water is added till the solution is acid, which is ascertained by litmus paper; it separates in crystals, the sulphate of soda remaining in solution.

CHAPTER XV.

CHLORINE, IODINE, BROMINE, AND FLUORINE.

436. *Chlorine* is a greenish yellow coloured gas, uninflammable, but supports the combustion of many substances. It was formerly called *oxymuriatic acid*. *Symb.* Cl—Equiv. 35·5. It has a pungent suffocating odour, acts with great energy on metals, and numerous inflammable substances abounding in

hydrogen. All vegetable and animal colouring matters, and offensive effluviæ from decomposed animal or vegetable matter, are quickly destroyed by it. Experiments with chlorine and its compounds should be performed, so that all the noxious fumes may be carried away, which are often very deleterious.

437. Heat cautiously in a retort 1 ounce of binoxide of manganese in fine powder, with 3 ounces by measure of aqueous hydrochloric acid; put the acid first into the retort. Collect the chlorine gas at the pneumatic trough, having heated the water previously to 90 degrees; chlorine is condensed by cold water. Remove the retort when the gas comes slowly away, to prevent accident from the regurgitation of the water; this is apt to take place when the chlorine and the steam accompanying it are absorbed rapidly by the water.

438. Hydrochloric acid consists of hydrogen and chlorine, and two particles of it with one of binoxide of manganese produce chlorine gas, water, and hydrochlorate of manganese, which remains in the retort. *Symb.* 2HCl&:Mn = Cl&·H&HCl·Mn.

439. If a portion of chlorine gas be required quickly, put a table-spoonful of chloride of lime (common bleaching powder) into a jar, and pour upon it an equal bulk of aqueous hydrochloric acid, covering the jar lightly with a tray, that part of the air may escape. The hydrochloric acid unites with the lime, and displaces the chlorine; procured in this way, it is often used for some experiments, but must be considered very impure, and is mixed with air and carbonic acid gas.

440. Kindle a suspended candle, and introduce it into a jar of chlorine; it attracts hydrogen from the inflammable matter; carbon is separated, and the candle burns with a lurid flame.

441. Into a detonating jar, two-thirds full of chlorine gas, introduce coal-gas till it is filled, invert quickly and apply a light; an explosion ensues, the chlorine takes hydrogen from the gas, produces hydrochloric acid, and carbon is deposited.

442. Mix equal bulks of chlorine and hydrogen gases in a detonating jar, and apply a light; they combine with explosion, and produce hydrochloric acid gas.

443. Pour antimony in powder through a funnel into chlorine gas; it takes fire as it combines with the chlorine.

444. Introduce copper leaf suspended in an iron cage into another jar; it also evolves heat and light as it combines with the chlorine.

445. Make a solution of chlorine in water, proceeding in the manner described in par. 347, page 75.

446. Add a portion of the solution to water tinged with vegetable blue; it is immediately bleached, the chlorine decomposing the colouring matter by taking hydrogen from it.

447. Chlorine is employed in numerous operations of art, from the many very valuable properties which it presents. It is used most extensively in combination with lime and water, forming then the compound termed *bleaching powder*. It is soluble in water, and acts most powerfully when an acid is added to detach the chlorine from the lime.

448. *Hypochlorous acid*, ·Cl, *chlorous acid*, ·:Cl, *chloric acid*, ·::Cl, and *perchloric acid*, ·:::Cl, are all compounds of chlorine and oxygen which are usually procured by indirect processes. They are not much employed in a pure form, but are produced in various operations when compounds containing chlorine are decomposed.

449. *Chlorous acid* is a transparent and very deep greenish yellow coloured gas. It is particularly distinguished by exploding with very great violence when subjected to a very moderate heat. Sometimes it explodes by the heat developed during its preparation, even when not more than three or four grains are used. It is usually prepared on a very small scale, by introducing four or five drops of aqueous sulphuric acid into a very stout glass, and allowing a grain or two grains of the chlorate of potassa to fall into it, the operator turning the mouth of the tube away from his face, as sometimes an explosion ensues when the materials come in contact. The gas is evolved as the aqueous sulphuric acid unites with the potassa. It is formed as part of the chloric acid which is then liberated loses one particle of oxygen, every two particles thus evolved combining with one of undecomposed chlorate of potassa, and forming perchlorate of potassa.

450. If hydrochloric acid be poured so as to cover a few grains of the same salt, chlorate of potassa, in a test tube, a very complicated reaction ensues, and chlorous acid is evolved; it is mingled, however, with a large quantity of chlorine. On introducing into the test tube a small wooden match, or a slip of paper, previously dipped in oil of turpentine, combustion immediately ensues. In this case, the reaction is not violent on the small scale, in consequence of the large amount of chlorine with which the chlorous acid is diluted. A larger portion of this gaseous mixture may be produced by mixing a teaspoonful of the salt with the aqueous hydrochloric acid in an ale glass.

451. *Chloric acid* is the principal compound of chlorine and oxygen. It is usually employed, in combination with potassa, in the form of chlorate of potassa. This salt is formed by the action of chlorine water and potassa.

452. Into an ale-glass put a teaspoonful of the crystals of chlorate of potassa, after filling it with cold water, and throw

upon them five or six chips of phosphorus, each about the size of a pea. Fill a pipette (fig. 79) with aqueous sulphuric acid, allowing the acid at first to drop through it, that all air may be expelled, then leave it in the glass, the extremity resting upon the crystals of the chlorate. As the acid slowly descends, it takes potassa from the salt, and disengages a compound of chlorine and oxygen, which inflames the phosphorus under water.

Fig. 79.

453. Triturate briskly in a mortar half a grain of chlorate of potassa with as much sulphur; it quickly takes oxygen from the chlorate, producing an explosion.

454. Mix two grains of sulphuret of antimony, four of sugar, and twelve of the chlorate of potassa, adding the latter cautiously on paper after mingling the two first, that there may be no explosion. If this mixture be heated, it takes fire at a very moderate elevation of temperature. If a portion be touched with a drop of strong aqueous sulphuric acid, lifted on the end of a slip of glass, chlorous acid is immediately evolved, which inflames the mixture.

455. Mix two grains of sugar with four of chlorate of potassa, a mixture is obtained which is affected much in the same manner as in the preceding case by heat and by aqueous sulphuric acid, though it is not quite so quick.

456. In both the preceding cases, when the mixture is inflamed as it is touched by the aqueous sulphuric acid, chlorous acid is liberated; and by its action with the inflammable matter of the sugar, the combustion is commenced, which is sustained actively by the large quantity of oxygen in the chlorate of potassa.

457. All these experiments must be cautiously performed; the gaseous compound of chlorine and oxygen explodes violently when gently heated. Many accidents have occurred from mixing chlorate of potassa and aqueous sulphuric acid in tubes and retorts.

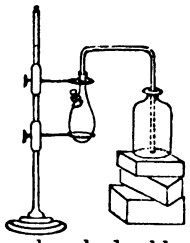
458. *Hydrochloric* or *muriatic acid* is a gas (see page 12), which is condensed in large quantity by water, forming the common aqueous hydrochloric acid, and is often termed *spirit of salt*. *Symb.* HCl—Equiv. 36·5.

459. Heat strong aqueous hydrochloric acid as it is obtained from the manufactory; hydrochloric acid gas is expelled from it, and may be collected in a flask or bottle as shown in fig. 80. When full of gas, remove the tube, close the mouth by the thumb, and place it, with the mouth downwards, under water coloured by vegetable blue; on removing the thumb, the water is forced with great rapidity into the bottle by the pressure of

the air; the water combines with the gas, and the vegetable blue is reddened.

460. Mix two drachms by measure of aqueous sulphuric acid in a flask with an equal bulk of water; when cold, pour it upon 200 grains of common salt in a retort, and apply heat, introducing the beak of the retort into a receiver one-third full of water, which must be kept cold; the retort should be large enough to contain two or three times as much materials as are used, and the beak of the retort, though placed in the water, should not be put under it. The sulphuric acid causes a decomposition of the common salt, which is composed of chlorine and sodium, and of the water; chlorine from one and hydrogen from the other produce hydrochloric acid gas, which is condensed by the water in the receiver. Sulphuric acid and soda, composed of sodium and the oxygen of the water, remain in the retort, forming sulphate of soda. *Symb.* ;S&ClNa&·H = ;S·Na&HCl.

Fig. 80.



461. Mix aqueous nitric and aqueous hydrochloric acids in a flask, and apply heat. Oxygen from the nitric and hydrogen from the hydrochloric acid combine and form water; nitrous acid and chlorine are then set at liberty. *Symb.* ::N&HCl = ·:N&·H&Cl.

This mixture is termed *nitro-hydrochloric acid*, and also *aqua regia*, as it dissolves gold; it is much used in dissolving metals when chlorine is required.

462. Add a solution of nitrate of silver to a solution of chlorine or common salt in water, or to diluted hydrochloric or nitro-hydrochloric acid; a white curdy-looking compound immediately falls, composed of chlorine and silver; it assumes a dark tint when exposed to the light, and is termed *chloride of silver*.

463. *Iodine* is an opaque solid having a bluish black colour and semi-metallic lustre. *Symb.* 1—Equiv. 126·5. It melts at 227 degrees, and boils at 350 degrees. Though very different in appearance from chlorine, it is similar to it in many of its properties; and has a pungent penetrating odour and an acrid taste. It is particularly distinguished by the deep violet coloured vapour which it forms when exposed to heat. Iodine is dissolved sparingly by water, but in large quantity by alcohol.

464. Heat a few grains of iodine in a flask; a beautiful violet-coloured vapour is observed, which condenses slowly in crystals.

465. Mix a solution of starch with a solution of iodine in water; a blue compound appears—the iodide of starch. Put a little into a flask, and pour boiling water upon it till the colour disappears; immediately afterwards pour it into cold water, and the colour is restored.

466. Iodine is obtained from sea-ware, after subjecting it to a number of complicated processes. A compound of iodine and potassium is much used for medicinal purposes, and in testing several metals.

467. Add a few drops of a solution of the iodide of potassium to starch; no effect is produced. Add to the mixture a little chlorine water or aqueous sulphuric acid to unite with the potassium and detach the iodine; it immediately produces the blue iodide of starch.

468. When iodine occurs in combination with hydrogen, in the form of hydriodic acid, it has no action with starch; but if chlorine water or aqueous sulphuric acid be added, the iodine is liberated as in the preceding case, and immediately the starch is affected in the usual manner.

469. *Bromine* is similar in properties to chlorine and iodine. It is the only element that is liquid at natural temperatures, with the exception of mercury. It has a deep hyacinthine red colour, and produces a ruddy vapour, resembling in appearance nitrous acid vapour. Bromine is found in sea-water in combination with hydrogen. The saline matter being concentrated by the evaporation of the principal portion of the water, chlorine is added, which detaches the bromine.

470. *Fluorine* is an element which has not hitherto been obtained in a pure form. Its most important compound is hydrofluoric acid, which is a compound of fluorine and hydrogen. *Hydrofluoric acid*, also called fluoric acid, may be prepared by adding aqueous sulphuric acid to pulverised fluor spar, which consists of fluorine and calcium; the fluorine unites with the hydrogen of the water, and produces the hydrofluoric acid; the calcium and the oxygen of the water form lime, and this combines with the sulphuric acid. It is transparent and colourless; it emits fumes on exposure to the air; it is particularly distinguished by forming a gaseous compound with silica, and cannot therefore be prepared in glass or other vessels in which this substance forms a part. It is used for etching on glass, but must be employed with extreme caution, as it is very corrosive.

CHAPTER XVI.

METALS.

471. Metals are said to be *native* when they occur uncombined with other substances; if in combination with other bodies, they are said to be *mineralised.* Metals are seldom obtained in a pure form in nature; they are generally combined with oxygen, sulphur, or chlorine, and often also with sulphuric, nitric, carbonic, and phosphoric acids. In preparing them from the minerals in which they occur, they are said to be *reduced* from their *ores.* Charcoal is employed to take away oxygen; and lime, carbonate of potassa or soda, or iron, to remove sulphur and chlorine. Where there is much earthy matter mixed with the ore of a common metal, alkalies, glass, or other earths are added, so as to form a fusible compound with them, through which the metal may fall; the substance added is usually called a *flux,* as it promotes the flowing or melting of the different ingredients which might otherwise prevent the particles of the metal from running together.

472. Metals are distinguished by their peculiar lustre and opacity; many of them are very malleable and ductile, being easily extended into thin leaves or drawn into fine wire. They are good conductors of heat and electricity, unite with many non-metallic bodies, when they lose in general all their lustre, and assume an earthy appearance.

473. Compounds of metals with oxygen, chlorine, and iodine, are termed *oxides, chlorides,* and *iodides.* With sulphur, phosphorus, and carbon, the compounds are termed *sulphurets, phosphurets,* and *carburets.* When an acid, the name of which terminates in *ic,* unites with an oxide, the name of the acid in the compound is made to terminate in *ate.* Thus, nitric acid uniting with potassa produces nitrate of potassa.

474. The great mass of solid compounds observed at the surface of the earth may be considered as oxidated metals; and, accordingly, air being a binoxide of nitrogen, water an oxide of hydrogen, and the greater number of earthy compounds consisting of oxidated metals, it may be affirmed that the greater mass of the globe consists essentially of oxidated bodies. In the interior, unoxidated metals have been supposed to predominate, but on this speculative point different opinions are entertained.

475. The metals are divided into three great classes:—

I. *Kaligenous metals,* which produce alkalies when combined with oxygen.

II. *Terrigenous metals*, which form earths of different kinds as they combine with oxygen.

III. *Calcigenous* or *common metals*, whose oxides have long been called *calces*.

476. The common metals are further subdivided according to the degree of force with which they attract oxygen.

I. Common metals whose oxides are not reduced by heat alone. Of these the following are the most important:—

Iron	Bismuth	Arsenic	Cerium
Lead	Manganese	Vanadium	Columbium
Copper	Chrome	Cadmium	Tellurium
Zinc	Cobalt	Tungsten	Titanium
Antimony	Nickel	Molybdenum	Uranium.
Tin			

II. Common metals whose oxides are reduced by heat alone. This class includes gold, silver, mercury, platinum, and other metals of less importance.

477. *Malleable* metals can be altered in form, and be made to assume different shapes, without losing their continuity of form or texture. They are said to be *laminable* when they can be rolled into plates or beat into thin leaves, and *ductile* when they can be drawn into wires. Separate pieces of some metals can be united at a high temperature by mechanical means, and formed into any shape. In such cases they are said to be *welded*. Common gold leaf is about the 200,000th of an inch in thickness, but silver leaf is only 100,000th of an inch thick.

478. Metals are exceedingly opaque, but would probably all transmit light could they be rendered sufficiently thin. Gold leaf transmits a greenish light. The *tenacity* of some metals, but more particularly of iron, is exceedingly great. An iron wire little more than two-thirds of an inch in diameter supports a weight of 549¼ pounds. The extent to which it is now used in the form of anchors, cables, machinery, bridges, buildings, wire ropes, &c., sufficiently demonstrates its importance in these respects. Next to iron, the metals having the most tenacity are copper, platinum, silver, gold, and zinc.

479. The *fusibility* of metals is exceedingly various. Mercury is fluid till cooled 72 degrees below the freezing-point of water; platinum is melted only by the most intense heat which furnaces can command. Lime, common salt, borax,

compounds of potassa, soda, and other substances, are constantly used as fluxes in melting metals. They melt on combining with different substances in the ore, if they are infusible alone, and are employed for different purposes.

I. To give fluidity to materials with which metals may be associated in extracting them from their ores.

II. To combine, at the same time that they melt, with various ingredients in combination with the metals.

III. To spread over the surface of metals, and exclude the action of the air.

480. In reducing metals from their ores, one metal is often mixed with metallic compounds, so as to take the place of others, and separate those that are most valuable. In other cases metals are extracted from various combinations by galvanic arrangements. (See page 49, par. 219.)

481. In the principal chemical changes into which they enter, metals are prone to combine with oxygen or other substances, before they combine with non-metallic compounds; acids, in particular, do not combine with metals when they are not previously united with other bodies. Metals lose their brilliant lustre, and generally present the appearance of earthy substances, when they combine with non-metallic bodies. Metals uniting with each other form *alloys*, and retain their lustre. *Amalgams* are metallic compounds containing mercury.

CHAPTER XVII.

POTASSIUM, POTASSA, NITRATE OF POTASSA.

482. The most important kaligenous metals are *potassium* and *sodium*, which, with oxygen, form potassa and soda. These have been termed *fixed alkalies*, as they are not easily converted into vapour, but ammonia, the volatile alkali, is a gas at natural temperatures. The alkalies turn vegetable blue to green, yellow turmeric to a reddish-brown, corrode animal and vegetable substances, and form soaps with oily and fatty substances. *Lithium* is the name given to another alkaline metal which is comparatively rare, and has not as yet been applied to important purposes.

483. *Potassium* is procured from potassa, by heating it powerfully with charcoal or iron; the process requires much attention; none who are not well acquainted with chemical manipulation should attempt to prepare it.

484. Potassium is particularly distinguished by its extreme

lightness, having a less specific gravity than water, so that it floats upon it when it is brought in contact with it. It is a very powerful chemical agent, having a great force of attraction, and entering into various combinations with the evolution of heat and light.

485. Throw a grain of potassium upon water; it takes fire and burns upon the surface of the water; potassa is formed, which is quickly dissolved.

486. Boil, in an iron goblet, 1 pound of newly slaked lime, in fine powder, with an equal weight of carbonate of potassa and 10 pounds of water; the carbonic acid unites with the lime, the potassa is left in solution. Put the mixture into an earthen or glass funnel, obstructed by a few fragments of glass and a piece of linen cloth; collect the solution in bottles as it escapes, drop by drop. Exclude it, during its preparation and afterwards, carefully from the air, otherwise the potassa attracts carbonic acid.

487. Fused potassa (common caustic) is procured by evaporating the solution, and fusing by an increased heat the dry matter that remains.

488. Add a solution of potassa, of the carbonate of potassa, or of the bicarbonate, to water tinged with vegetable blue; a fine green is perceived. Add, drop by drop, aqueous sulphuric, nitric, or hydrochloric acid, to the green liquid; the acid combines with the alkali, and the blue colour is at last restored. Similar experiments may be performed with other acids.

489. The quantity of potassa in pot-ashes or pearl-ashes is ascertained in the above manner, every 49 grains of aqueous sulphuric acid required to restore the blue colour in a solution of the alkali tinged by the colouring matter of the cabbage, indicating 48 of potassa $= K + O$. As acids and alkalies combine, they lose their causticity as well as their power of affecting vegetable colours, and are said to *neutralise* each other.

490. Burn a few small pieces of wood, collect the ash that remains, pour water upon it, and add vegetable blue. Potassa is found in solution, which turns the blue to a green. The pot-ashes of commerce are prepared from the ashes of burned wood.

491. Expose pearl-ashes (impure carbonate of potassa) to the air in a cup or plate, it soon deliquesces. (See page 26, par. 114.)

492. Heat an ounce or two of nitre in a crucible; it soon melts, and if heated much, oxygen escapes, but no combustion is observed. While red-hot, pour upon it small successive quantities of sulphur and charcoal in fine powder, avoiding the fumes; the charcoal and sulphur burn quickly as they receive oxygen from the nitre.

493. Throw some nitre upon red-hot cinders; they burn with great rapidity.

494. Dissolve nitre in boiling water, so long as any is taken up; crystals of nitre in six-sided prisms appear as the solution cools.

495. Dip paper into the solution which remains above the crystals, dry it, and apply a light; it burns quickly, forming common match-paper.

496. Mix intimately 75 grains of nitre, 15 of sulphur, and 10 of charcoal. The mixture deflagrates like *gunpowder* when heated; machinery is required to give it the granular appearance of gunpowder.

497. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony. This mixture is termed the blue signal light, which is seen, when inflamed, at a great distance.

498. Nitre occurs in the soil in India, and is also formed artificially. In all deflagrating mixtures containing nitre, oxygen is rapidly transferred from the nitric acid to the inflammable matter.

499. Heat *bitartrate of potassa* (*cream of tartar*), consisting of tartaric acid and potassa, in a crucible; it is soon blackened, as the tartaric acid is decomposed. A small quantity held on a slip of glass presents the same appearance. Water poured upon the black matter dissolves the potassa; it may be tried by the vegetable blue, which becomes green as before.

500. Heat in the same manner equal weights of cream of tartar and nitre; the potassa of both remains united with carbonic acid, which is formed as the carbon of the tartaric acid unites with oxygen from the nitric acid in the nitre. In this manner very pure carbonate of potassa is formed.

501. Add a solution of tartaric acid to a strong solution of any salt of potassa; crystals of cream of tartar soon appear. Cream of tartar is usually procured from the juice of the grape being deposited in crystals.*

CHAPTER XVIII.

SODA.

502. Soda = sodium 24 + oxygen 8. Sodium and soda are similar to potassium and potassa in all their leading properties. Soda is obtained principally from common salt and aqueous sulphuric acid, when the changes described in 640 take place.

* See experiments described under Chloric Acid, and Chlorate of Potassa, in page 101.

The sulphuric acid is withdrawn afterwards, and replaced by carbonic acid on heating the sulphate of soda with charcoal and chalk. Water dissolves the carbonate of soda, which is then crystallised, forming the compound usually termed soda.

503. *Kelp* and *barilla* are the ashes that remain after burning sea-ware. Soda has long been extracted from them by the action of water.

504. *Chloride of sodium* or *common salt* = 35·5 chlorine + 23·5 sodium = 59. When procured by evaporating sea-water slowly by the action of the sun in warm climates, after allowing it to overflow fields from which the sea is afterwards excluded, it is termed *bay salt*. *Pan salt* is obtained by boiling rapidly sea-water in an iron pan. *Rock salt* is the term applied when it is dug out of salt mines, many of which, of great extent, and containing often very pure salt, are found in different parts of the globe.

505. Common salt crystallises in cubes, which are often associated so as to form hollow pyramids.

506. Throw some crystals of bay salt upon a red-hot plate of iron, they fall in pieces quickly with a loud decrepitating noise; the experimenter must avoid the fragments as the crystals break.

507. Dissolve common salt in boiling water, and add a solution of carbonate of soda; if common salt be pure, no effect appears, but if any magnesia be present, it soon appears as a white powder.

508. When magnesian salts are mixed with common salt, which is often the case, it is very apt to attract moisture, and acquires a bitter disagreeable taste; it is also much less fit for curing meat.

509. *Biborate of soda*, or *borax*, contains two particles of boracic acid and one of soda, with water of crystallisation. Heat 200 grains in a crucible capable of holding 800; the water is expelled; the dry borax is fused into a transparent and colourless glass.

510. Mix a teaspoonful of powdered borax with an equal bulk of aqueous sulphuric acid in an evaporating basin; add half an ounce of alcohol. Heat the mixture and kindle the alcohol; the sulphuric acid unites with the soda, and the alcohol burns with a beautiful green flame, in consequence of the presence of the boracic acid.

CHAPTER XIX.

AMMONIA.*

511. Ammonia 17 = nitrogen 14 + hydrogen 3 = NH^3. A gaseous compound, alkaline like potassa, and often termed spirit of hartshorn, being formed when the horn of the deer and most animal substances are heated, the air being excluded; it is also formed in large quantity during the preparation of coal-gas. It is usually combined with hydrochloric acid, from which it is separated again by lime, to prepare it free from the offensive odour of animal matter, which at first it always presents. Being condensed in large quantity by water, it is usually employed in combination with this substance.

512. Heat half an ounce of strong aqueous ammonia in a small flask, receiving the gas, which is lighter than air, in another flask, as in fig. 81. The air is soon expelled, and then the flask must be removed, proceeding as described in 459. The coloured water is forced with great rapidity into the flask by the pressure of the air as the ammoniacal gas combines with it, and immediately becomes green.

Fig. 81.

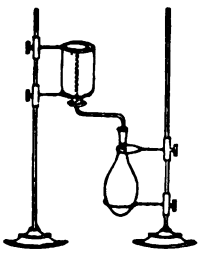


Fig. 82.

513. Put a drachm of strong aqueous hydrochloric acid into any flask, vase, or bottle, and a drachm of strong aqueous ammonia into another, then connect them by a tube passing through a cork which fits the bottle (fig. 82.) White fumes

* Ammonia is inserted here, though it contains no metallic matter, as it is very similar to the alkalies in most of its properties.

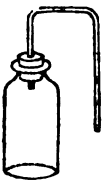
of hydrochlorate of ammonia, or sal-ammoniac, immediately appear.

514. If no apparatus peculiarly adapted for the preparation of ammonia can be procured, mix 150 grains of hydrochlorate of ammonia with 100 of slaked lime in fine powder; heat the mixture in a glass retort by a lamp or chauffer, and condense the gas in a receiver half full of water. Shake the receiver frequently, but always keep the beak of the retort out of the water.

515. Hold test papers above aqueous ammonia; the ammoniacal gas escaping from the aqueous ammonia, affects them in the same manner as alkalies. Expose them to a very gentle heat, the ammonia is expelled, and the original colour is restored.

516. Prepare sulphureted hydrogen gas in a phial with a bent tube (fig. 83), passing the gas into an ounce of common aqueous ammonia contained in another phial; a large quantity combines with the ammonia; the solution is now termed *hydrosulphuret of ammonia*, and is often much used instead of sulphureted hydrogen gas in testing metals.

Fig. 83.



517. Dissolve oxalic acid in water, and add carbonate of ammonia till the solution no longer reddens the blue test-paper; the oxalic acid unites with the ammonia in the carbonate, expelling the carbonic acid with effervescence.

518. Heat a little of any salt suspected to contain ammonia with an equal bulk of slaked lime in a test-tube; ammoniacal gas is expelled if any be present, and may be recognised by its odour, or by the white fumes it produces when brought in contact with a rod dipped in hydrochloric acid. Soda or potassa may be used instead of lime.

CHAPTER XX.

LIME.—PLASTER OF PARIS.

519. Earths are composed of metals and oxygen, in the same manner as the alkalies, potassa, and soda; four of them, lime, baryta, strontia, and magnesia, resemble alkalies; but they are not fused by heat, they are less soluble in water, less caustic, and form insoluble compounds with carbonic acid.

520. *Limestone*, *chalk*, *marble*, and *calcareous spar*, are composed principally of carbonic acid and lime, and are called *car-*

bonates of lime. Heat a few fragments of limestone or marble in an open fire; 50 parts of pure carbonate lose 22 of carbonic acid gas, and 28 of lime remain. In this condition it is termed *quick lime*, or *burned lime.*

521. Dip the quick lime into water, remove it immediately, and cover it. It soon swells, and falls to powder, combining with the water it had absorbed; the compound is termed *slaked lime*, or *hydrate of lime.*

522. Put a table-spoonful of slaked lime into a beer bottle nearly full of water; shake the bottle, and allow the undissolved lime to subside; or filter, excluding the air, if a solution of lime be quickly required. It is termed *lime-water.* Try it with vegetable blue and turmeric in solution; it affects them in the same manner as alkalies.

523. Expose lime-water in any vessel to the air; it soon attracts carbonic acid, and a crust of carbonate of lime appears upon the surface. Mortar used in building is composed of sand and lime mixed with water, and hardens as the lime attracts carbonic acid.

524. Put 1 or 2 ounces of lime-water into a glass jar, and add carbonic acid water (347); carbonate of lime falls; add more carbonic acid water, and the carbonate is dissolved. Many natural waters contain lime dissolved by excess of carbonic acid; exposed to the air, the excess escapes, and carbonate of lime is deposited, encrusting with a stony matter any substance upon which it may fall.

525. Pour aqueous hydrochloric acid diluted with twice its bulk of water upon fragments of carbonate of lime, so long as any effervescence appears. The changes described in 344 take place. Any mineral which dissolves with effervescence in diluted hydrochloric acid, and which gives a mass that slacks like lime, after heating to redness for some time, may be regarded as a limestone.

526. Take the solution of hydrochlorate of lime prepared as above (525); pour a portion into five or six wine-glasses; leave one as it is, and add different quantities of water to the rest. On mixing aqueous sulphuric acid with each, different phenomena are presented. Where no water is added, the mixture becomes solid, sulphate of lime falls, composed of sulphuric acid and lime; hydrochloric acid gas escapes, which must be avoided. In the others, the hydrochloric acid is retained by the water, and the sulphate of lime is precipitated, unless a large quantity of water be present to dissolve it.

527. Mix with water powdered sulphate of lime (which has been heated previously to expel water) so as to form a thick fluid like cream. Put it in this condition into any mould or

upon any coin, so as to take an impression; it gradually combines with the water, and forms a solid compound. The powder is usually termed plaster of Paris, as the mineral from which it is made abounds at Paris.

528. Add a solution of carbonate of soda to a solution of hydrochlorate of lime; carbonate of lime falls, the other substances remain in solution.

529. Add oxalate of ammonia to any solution of lime, neutralising it at first with ammonia if it be acid; oxalate of lime, which is very insoluble, immediately appears.

530. *Hydrochlorate of lime* in powder attracts moisture quickly from the air, and is much used in drying gases.

531. *Chloride of lime* is formed by exposing slaked lime in powder to chlorine gas. Water dissolves it abundantly, and the solution is much used as it abounds in chlorine. The chlorine acts most effectually when acids are added to detach the lime.

CHAPTER XXI.

BARYTA, STRONTIA, AND MAGNESIA.

532. *Baryta* is similar to lime, and is used principally as it detects sulphuric acid when added to any solution containing it.

533. *Strontia* also resembles lime. It is used in the preparation of deflagrating mixtures, where a bright crimson light is required. Mix hydrochlorate or nitrate of strontia with alcohol in an evaporating basin or metallic cup, inflaming it, and heating the mixture. The alcohol burns with a crimson tint. A large sheet of paper dipped in the mixture and inflamed, shows the tint very distinctly.

534. *Magnesia* is found in bittern, the liquid that remains after boiling down sea-water for the preparation of common salt; it is there combined principally with sulphuric and hydrochloric acids. It is also found in some varieties of limestone, and in many natural waters. Magnesia is mild compared with the preceding earths, and does not corrode animal substances, so that it is often given medicinally to neutralise acids. It is very sparingly soluble in water.

535. *Sulphate of magnesia*, or *Epsom salts*, contain sulphuric acid and magnesia; they are prepared by crystallisation from bittern, or from natural waters in which it abounds. Many fatal accidents occurring frequently in consequence of its being *mistaken for Epsom* salts (sulphate of magnesia), the following

characters ought to be studied experimentally; the last two may be seen by putting the materials in small quantity upon a slip of glass, adding the tests in solution.

Tests.	Oxalic Acid.	Sulphate of Magnesia.
Taste,	Acid,	Bitter.
On red-hot cinders,	Dissipated,	White mass left.
Vegetable blue,	Reddened,	No effect.
Alkaline carbonates,	Effervesces,	White precipitate.

Symb. of oxalic acid. $:C^2=O^3+C^2$, or $=\cdot C+:C=36$.

CHAPTER XXII.

ALUMINA.—SILICA.

536. *Alumina*, or oxide of aluminum, abounds in clay, and is distinguished from preceding earths by its insolubility in water, and by being soluble in a solution of potassa. When uncombined, it is insipid and inert.

537. *Alum* is one of its principal compounds, and contains alumina, potassa, sulphuric acid, and much water of crystallisation. Its solution reddens litmus, but scarcely affects cabbage.

538. Add a little ammonia, potassa, or soda, to a solution of alum; it unites with part of the acid, and the alumina falls.

539. Heat alum in a red-hot iron cup; it soon melts, water of crystallisation is expelled, and a spongy mass is obtained, termed *burned alum*.

540. *Common clay* may be fused by a sharp heat, and becomes red before it melts, the iron it contains attracting oxygen.

541. Fire-clay is less fusible, and is used in preparing bricks, which may be exposed in furnaces to a strong heat. Fine varieties of clay are used in the manufacture of *crucibles*, *pottery-ware*, and *porcelain*.

542. *Silica* consists of silicum 22 + oxygen 8; it is, like alumina, a very abundant earth, constituting the principal ingredient of flint, of the sand of the sea and of the desert, and of many rocks and minerals. Quartz is composed of silica nearly pure. Silica, in its ordinary form, is insoluble in water.

543. If sand or any siliceous compound, such as glass, be mingled with aqueous sulphuric acid and fluor spar (par. 470, page 104), the hydrofluoric acid that is disengaged on the application of heat combines with part of the silica, and forms a

transparent colourless acid gas. It produces fumes when exposed to the air, but is particularly distinguished by the manner in which it is decomposed if introduced from the beak of a retort in water, the hydrofluoric acid combining with the water, while the silica is separated in the solid form. The experiment may be performed with a small glass retort containing 100 grains of each material. The retort is generally corroded in one or two operations.

544. Mix intimately 200 grains of fine sand, and 600 of pure carbonate of potassa; fuse the mixture in a crucible capable of containing four times as much. Carbonic acid escapes, the silica and potassa combine and produce glass. Pour out the glass, which is commonly termed *silicated potassa*, on an iron-plate, and dissolve it in water, the large quantity of alkali rendering it soluble in this fluid. The compound formed in this manner constitutes pure *silica soap*, having all the detergent properties of common soap; it is more active than ordinary soap, and leaves a harsh feeling upon the hand. Common silica soap is mixed with a considerable portion of common soap, and occasionally with sand.

545. Add to the solution hydrochlorate of ammonia, also in solution. The hydrochloric acid of the hydrochlorate unites with the potassa of the glass, and the silica falls.

546. With less alkali, glass is formed insoluble in water. *Common bottle glass* is made of coarse sand, and any alkaline salt or earthy matter which can render it fluid when heated. *Plate* and *window glass* are made with purer sand and alkali. *Flint glass* is composed of similar materials, with the addition of oxide of lead, which gives more weight and lustre to the glass, and also allows it to be worked at a reduced temperature.

547. *Coloured glasses* are formed by heating glass with various metallic oxides. Cobalt gives a fine blue; with manganese an amethystine tint is seen. Gold produces a ruby colour; copper and chrome give green.

548. All vessels made of glass must be cooled slowly after they are made, or annealed, as this is termed, otherwise they are very easily broken. When a piece of any fused rock or glass is cooled with extreme slowness from a high temperature till it becomes solid, it crystallises, and presents the appearance of a stone. But if cooled quickly, a glassy substance is observed.

CHAPTER XXIII.

COMMON METALS.—IRON.

549. This, the most important of the metals (see par. 21, page 10), is found in a great variety of forms at the surface of the globe, and is obtained principally from various ores in which it is combined with oxygen. These are sometimes nearly pure, and then, by the action of carbon alone, the metallic iron is procured, as the carbon removes oxygen on the application of heat. In this country the ores more commonly employed, which are termed clay-iron ores, require the addition of lime, which forms a fusible compound with the other earthy matter in the ore, through which the iron falls with facility when the carbon has removed the oxygen.

550. In many places the air propelled into the furnace for preparing the iron is heated previously by passing it through red-hot iron pipes. If cold air be blown into a furnace, its first effect is to cool the fuel and other matters with which it comes in contact, at the very point where the greatest intensity of heat is required, however great the heat may be that is afterwards developed. When the air is heated previously, the greatest intensity of heat is produced at the point where it is most important that the temperature should be as high as possible. When air at ordinary temperatures is used, the furnace is said to be a *cold blast furnace*, but when warm air is employed, it is called a *hot blast furnace*. In all blast furnaces the great intensity of the heat fuses all the earthy substances, which are run off from time to time in a liquid form, these consolidating as they cool into a glassy or stony-looking mass usually termed *slag*. The melted iron which accumulates at the bottom of the furnace is also allowed to run out from time to time by tapping the furnace, being received into numerous furrows made in sand; from these it acquires the form in which it is usually observed.

551. *Pig*, or *cast-iron*, is the term commonly given to iron as it is prepared from the clay-iron ore. It is more brittle and fusible than pure iron, in consequence of the presence of aluminum, silicum, and carbon in small proportion. It varies much in strength and fusibility, according to the source from which the ore is obtained, and the manner in which it is treated at different iron-works. *White cast-iron* is much harder and more brittle than *grey cast-iron*.

552. *Malleable iron*, termed also *soft*, *wrought*, or *forged iron*,

is prepared from common cast-iron by different operations. It is melted in the *refining* furnace, where a considerable quantity of impurities is separated. It is then transferred to the *puddling* furnace, a particular kind of reverberatory furnace (par. 392, page 86), where, after being melted, it is stirred assiduously till it becomes reduced to a solid form, presenting the appearance of a very coarse-looking granulated mass. By increasing the heat, it is then formed into balls, diminishing in fusibility as it increases in tenacity and purity. Lastly, by hammering it, and pressing it between rollers, the more fluid impurities still adhering to it are squeezed out, and it then forms the malleable iron of commerce.

553. Where a very pure oxide of iron is obtained at first, malleable iron is at once procured when the oxygen is removed.

554. Steel consists of iron and a small portion of carbon, varying from 100th to 150th part of its weight. It is usually formed by the process of *cementation*, an operation in which malleable iron, embedded in charcoal, is exposed for several days to a steady heat in a furnace. Steel is particularly distinguished by the extreme hardness which it acquires, if it be cooled suddenly after exposing it to heat. The *tempering* of steel consists in cooling it after exposing it to a particular temperature, so that it may acquire as it cools that particular quality or texture which may adapt it more especially for the purpose to which it is to be applied.

555. Iron is a metal which is extremely prone to rust when it comes in contact with air and moisture. In air absolutely dry, and in water absolutely free from air, it undergoes no change; but when both act upon it at the same time, the absorption of oxygen is rapid, particularly if any acid be brought in contact with the mixture. Even carbonic acid is powerful in promoting the oxidation of iron, if mingled with the water brought in contact with the iron. Iron becomes still more liable to rust and decay, if it be at the same time made to touch another metal such as lead, which induces a galvanic action that facilitates the absorption of oxygen. But iron brought in contact with zinc, and even a solution of the hydrochlorate of zinc, resists the oxidating influence of the air.

556. Put a teaspoonful of iron-filings on a plate, moistening them from day to day till they become *rust*, by attracting oxygen from the air, and a little carbonic acid and nitrogen.

557. Moisten a similar quantity in any flask or jar, and pour cautiously an equal bulk of aqueous nitric acid upon them. It is rapidly decomposed; nitrous acid escapes, and the iron is oxidated.

558. Prepare a coil of thin iron-wire, tie a thread at the

extremity, dip it in melted sulphur, inflame it, and introduce it into a bottomless bottle of oxygen, after placing it in a basin with water, as in fig. 84, with a plate of iron, or some sand, below. The iron oxidates, the oxide melting and falling through the water.

Fig. 84.

559. Mix, in a flask or jar, the materials employed in preparing hydrogen, using iron instead of zinc. (See 248, 249, and 259.) Filter the liquid procured, and, if no crystals appear, evaporate the solution, and set it aside, that green crystals of *sulphate of iron* may be formed.

560. The *black oxide* of iron, called by many the oxide, is a combination of the oxide with the peroxide; the oxide is obtained with difficulty in a pure form, on account of its tendency to absorb oxygen from the air. Fill a crucible half full of crystals of sulphate of iron, and expose it to a dull red heat, *red oxide* of iron, called also *peroxide*, remains; the oxide in the sulphate attracting oxygen from part of the acid as it is expelled by the heat.

561. Compounds of the oxide with acids are usually green, but the red oxide, which is nearly the same as rust, produces reddish compounds. Mix an ounce, by measure, of aqueous hydrochloric acid with six ounces of water and a small tablespoonful of the red oxide in a flask; keep the mixture in a warm place for some hours, shaking it occasionally, and filter it afterwards, to separate the solution from any excess of iron. The compound is termed *perhydrochlorate of iron*.

562. Mix 500 grains of flour of sulphur with 1000 of bright iron-filings in a Florence flask, and heat it on a chauffer of red-hot cinders. Heat and light are evolved as they combine, and sulphuret of iron is formed.

563. Dissolve 50 grains of sulphate of iron (*green vitriol*) in 2 ounces of water, and pour a few drops into 6 glasses, jars, or flasks, previously filled nearly full of water.

I. Into one pour potassa in solution; oxide of iron falls, combined with water. Expose it to the air; it slowly attracts oxygen, and becomes rust.

II. To another, add carbonate of potassa; carbonate of iron falls.

III. Add a little of the third to a large quantity of lime-water; oxide of iron is again precipitated.

IV. Add ferroprussiate of potassa in solution to the fourth. (See 4.)

V. Add to the fifth a drop of hydrosulphuret of ammonia;

sulphuret of iron is precipitated. $HS + NH^3 \& :S{\cdot}Fe = SFe\&{\cdot}H\&:S + NH^3$.

564. In all these experiments, the sulphuric acid remains in solution with the alkali or earth in the precipitating solution employed.

VI. Add an infusion of galls to the sixth; gallate of iron, the colouring matter of ink, slowly appears.

565. Dilute a little ink with water, and add chlorine water or oxalic acid; the colour disappears.

566. Repeat all these experiments, using a solution of the perhydrochlorate of iron diluted in the same manner as the sulphate. Observe the difference of tint in most of the precipitates formed from this solution.

LEAD.

567. *Lead* is a malleable and sectile metal, of a bluish-grey colour. It is employed in numerous processes of art, and is very generally used for protecting roofs, conveying water, and lining cisterns containing it. It is speedily oxidated by exposure to air and heat, and some waters corrode it rapidly, while others exert little or no action upon it. (See par. 228, page 52.) Minute quantities of different salts protect the lead from corrosion, 1 part of sulphate of soda in 4000 of water, or 1 part of phosphate of soda in 27,000, being sufficient for this purpose; in these cases, the phosphoric and sulphuric acids form compounds with a minute quantity of the lead, which adhere so tenaciously to it that they prevent further corrosion.

568. Lead also is particularly distinguished by the poisonous properties observed in many of its compounds. Few substances have proved more noxious in this respect than sugar of lead; in many cases death might have been prevented had the properties of this substance been known. It may be recognised with facility by merely heating a small portion about the size of a pea over the flame of a lamp or candle, when the following appearances are successively observed:—Fusion, boiling (from the water of crystallisation escaping), after which a dry white mass is left, dry fusion, escape of acetic acid, producing a smell of vinegar, the fused material becoming successively black and brown, and ultimately taking fire; after which red and yellow oxides of lead, and metallic lead, may then be observed.

569. Heat lead to redness in a crucible or iron ladle; it soon oxidates if exposed to the air, and the oxide melts. *Red oxide*, or *yellow oxide* of lead, in powder, is obtained if it be cautiously heated without being fused. Observe the beautiful iridescence

as, on removing the oxide from the surface, a fresh portion of metal is exposed to the air.

570. Dissolve 200 grains of acetate of lead (sugar of lead) in 4½ ounces of water, filter it, and pour a part into twelve different glasses. To the first six add the re-agents described in par. 563, page 119. Potassa and lime separate the oxide. Carbonate of potassa gives carbonate of lead. The hydrosulphuret of ammonia gives black sulphuret of lead, and is much employed in detecting this metal in solution. All the other substances produce white precipitates.

571. To the seventh glass add sulphuric acid or any sulphate in solution; white sulphate of lead falls. To the eighth add hydrochloric acid or any hydrochlorate; white chloride of lead appears. With the ninth mix a solution of iodide of potassium: yellow iodide of lead is precipitated. To the tenth add a solution of chromate of potassa; yellow chromate of lead is precipitated.

572. In the eleventh put a small fragment of zinc; it takes away all the acetic acid and oxygen, and lead is slowly deposited in crystals. The last experiment may be varied by diluting the solution with an equal bulk of water, placing it in a narrow glass, and suspending the zinc at the top of the solution. The lead appears in an arborescent form, producing what is commonly termed the *lead tree.*

573. Acetic and nitric acids act most powerfully on lead, corroding it, and forming compounds soluble in water. Oxide of lead is used in glazing pottery ware, and is often dissolved by vinegar or other acescent substances, which then become poisonous. Sulphureted hydrogen gas alone, or in combination with ammonia, is used to detect lead (570.) Waters abounding in carbonic acid corrode lead, and become unfit for daily use when kept in leaden cisterns.

COPPER.

574. Expose copper to a dull red heat for half an hour, allowing the air to play freely upon it, and then plunge it suddenly under water; the oxide formed on the surface is speedily separated, and the metal presents its proper metallic lustre.

575. Put several slips of copper into 2 drachms of nitric acid, diluted with twice their bulk of water. The copper is quickly dissolved, part of the acid communicating oxygen, the rest combining with the oxidated metal.

576. Put a plate of iron into a solution of sulphate of copper (blue vitriol). The copper appears in the metallic form, the

iron uniting with all the acid and oxygen previously combined with it.

577. If fragments of zinc, or a few iron nails, be boiled with any solution of copper in an acid, the whole of the copper is soon precipitated.

578. Add a little ammonia to a solution of copper; the oxide is immediately precipitated; on adding more, the liquid assumes a deep blue colour, and the oxide is dissolved. Copper and brass vessels (brass consists of copper and zinc) are frequently corroded when incautiously used in some culinary operations; as its solutions are poisonous, liquids suspected to contain it ought to be tested by adding ammonia to them, observing if a deep blue colour be produced, which indicates the presence of copper.

579. Arrange six glasses, each containing a solution of sulphate of copper, prepared in the same manner as the sulphate of iron solutions described in 563. Add to them the tests directed to be applied to the sulphate of iron; similar changes take place, but the tints are different.

ZINC.

580. Zinc is a brittle metal, having a white colour with a shade of blue.

581. Heat a few fragments of zinc to bright redness in an open fire, or in a crucible. The zinc is soon converted into vapour, and burns with a brilliant flame as it acts on the oxygen of the air.

582. Melt 600 grains of copper in a crucible, heating it to bright redness in a furnace, and covering it with a teaspoonful of salt or charcoal to exclude the air. Add 200 grains of zinc previously well heated, that it may be freed from every trace of moisture, and mix them well by stirring with an iron rod. Brass is formed as the copper and zinc combine. Remove any oxide when it is cold by a file, and the yellow colour of the brass becomes apparent.

583. The hydrochlorate of zinc has been lately used to a great extent by Sir William Burnett for protecting numerous vegetable substances from decay. For this purpose, the substance to be protected, as wood, cordage, or sailcloth, is steeped in a solution, and then dried.

TIN.

584. Tin has a brilliant white appearance when pure, and is malleable and ductile. Heat tin in a crucible; it is soon covered with an infusible oxide.

585. Pour upon tin, in fragments, a little aqueous nitric acid,

diluted with an equal bulk of water; the tin quickly attracts oxygen, and assumes the form of a white powder.

BISMUTH.

586. Bismuth is a brittle metal, having a white colour with a shade of red. Heated in a crucible, it oxidates much in the same manner as lead. It is distinguished by its great fusibility, a property which many of its compounds also present.

587. Heat 800 grains of bismuth, with 400 of tin and 400 of lead, in a crucible till they melt. A compound is formed so fusible that it becomes liquid when heated to 204 degrees.

588. Melt half of the above in boiling water, and add 100 grains of mercury; the compound now becomes fluid at 170 degrees. Many toys are made of this composition, which melt when they are put into warm fluids.

ANTIMONY.

589. This is a very brittle metal, having a brilliant white colour and metallic lustre. Mix intimately in a crucible 400 grains of iron-filings and 800 of sulphuret of antimony; heat the mixture to bright redness in a crucible, then add 100 grains of nitre in powder; on breaking the crucible when it is cold, with a hammer, the antimony will be seen below, and a compound of sulphur and iron above. The nitre promotes the separation of the antimony.

590. Mix 600 grains of nitre, 200 of sulphur, and 100 of sulphuret of antimony; place it upon an iron or earthen cup, and apply a lighted match. A brilliant deflagration takes place; the mixture is termed the *blue signal light*. It can be seen at the distance of fifty miles.

CHROME, MANGANESE, ARSENIC, AND COBALT.

591. CHROME.—The most important compound of this metal is the bichromate of potassa, which is commonly prepared by heating the ore with nitre, when the chrome becomes chromic acid by attracting oxygen from the nitre; it combines at the same time with the potassa, part of which is afterwards withdrawn by another acid.

592. Heat a few grains of the bichromate to redness; part of the chromic acid loses oxygen, and becomes green oxide of chrome.

593. Prepare five glasses, each containing a little of the bichromate in solution.

I. Add to one carbonate of potassa in solution; it combines with the excess of acid, and yellow chromate of potassa is formed.

II. Proceed as in par. 47, page 15.

III. Add nitrate of mercury in solution to the third glass; chromate of mercury falls, in the form of an orange-coloured powder.

IV. Mix a few drops of a solution of nitrate of silver with the bichromate in the next glass. Brick-red chromate of silver is seen.

594. Mix intimately 95 grains of the bichromate with 110 of common salt; heat the mixture in a retort with 2½ drachms by measure of aqueous sulphuric acid. Chlorine and chrome, or oxide of chrome, combine and produce a brilliant ruby-coloured vapour, *chlorochromic acid*, which may be condensed in a receiver; carry off the fumes as the process advances. Pour the product into three wine glasses, and add cautiously a drop of alcohol to one, of aqueous ammonia to the second, and a grain or two of sulphur to the third. In each case, heat and light appear, from the action of the chlorine on the hydrogen of the first two compounds, or on the sulphur, and green oxide of chrome is at the same time seen. These substances should be suspended at the extremity of a long cane, before they are added to the fluid.

595. MANGANESE.—Heat 100 grains of the binoxide (common peroxide) of manganese with 300 of nitre, in a crucible, to redness for half an hour. It attracts oxygen from the nitre, and unites with the potassa; water dissolves it, giving a fine green-coloured solution, which becomes purple and of a pinkish hue as it is merely exposed to the air, or diluted with an additional quantity of water. Hot water induces these changes much more speedily than cold water.

596. ARSENIC.—The violent poison known by this name consists of oxygen and the metal arsenic: it may be distinguished by the following characters:—Heat a grain in a dry test-tube; it is volatilised, and condenses on the sides of the tube in crystals, which have a brilliant lustre.

597. Heat a grain in another tube, after mixing it with twice its bulk of charcoal. Metallic arsenic condenses on the side of the tube, presenting a steel-grey lustre.

598. Mix a little with a drop of a solution of nitrate of silver, and add a minute quantity of potassa; yellow-coloured arsenite of copper is seen. Treat another portion in the same way with sulphate of copper; a similar action takes place, and grass-green arsenite of copper appears. Add a little boiling water in both cases, if the proper tint is not seen at first.

599. COBALT.—Write on paper with a dilute solution of hydrochlorate of cobalt; nothing is observed when it is dry; heat it, and the characters traced with it appear of a fine blue colour. If the solution be mixed previously with common salt, a green tint appears. The colour fades again on cooling.

MERCURY, SILVER, GOLD, AND PLATINUM.

600. Mercury or quicksilver. Boil 10 or 12 grains of mercury in a test-tube, holding it in the flame of a spirit-lamp. It rises in vapour, and condenses in brilliant globules in the upper part of the tube.

601. Heat 20 grains of mercury in a small evaporating basin, with 1 drachm by measure of nitric acid; much gas is evolved; the mercury takes oxygen from part of the acid, and combines with the rest. Heat the liquid till a dry mass appears, and then increase it gently till it becomes of a very deep red. Binoxide of mercury is thus obtained, which brightens as it cools, and presents small crystals. Heat a few grains in a test-tube, placing it in a spirit-lamp; oxygen is expelled, and the mercury volatilised, condensing ultimately, as in 600.

602. Mix 20 grains of mercury with one-third of the acid directed above, dilute it with three times its bulk of water, and allow the action to go on with little heat. A nitrate is formed, in which the mercury has little oxygen combined with it.

603. Heat in a test-tube, as in 600, 20 grains of mercury and 3 grains and one-half of sulphur. They combine, and produce *vermillion*, or *bisulphuret of mercury*, which assumes its usual tint when reduced to powder; it is obtained with a brilliant hue only by slowly or repeatedly subliming it.

604. Heat 20 grains of mercury and 25 of iodine in the same manner; a brilliant yellow biniodide is produced, which soon assumes a scarlet hue.

605. Dissolve a few grains of *bichloride of mercury*, a virulent poison, in an ounce of water, and divide it into four portions. Potassa and lime-water separate binoxide, the mercury deriving oxygen from the water. Iodide of potassium produces biniodide of mercury. Hydrosulphuret of ammonia gives bisulphuret of mercury, dark in colour till it is sublimed.

606. Animal and vegetable matters subject to decay in damp situations, as wood and canvass, are often steeped in a solution of the bichloride to preserve them.

607. Put a piece of tin-foil, two inches long by one broad, upon a sheet of paper; drop a little mercury upon it, spreading it upon the tin with a hare's foot. Cover it with a slip of paper twice its own length, and place over the paper any plain

piece of glass. On drawing out the paper, pressing down the glass all the time, the tin and mercury adhere to the glass, so as to produce a small looking-glass.

608. SILVER.—This metal is distinguished by its pure white colour and brilliant lustre. It is very malleable and ductile.

609. Add silver in fragments to aqueous nitric acid, exposed to heat, and diluted with three times its bulk of water, so long as it is dissolved. Part of the acid is decomposed, oxidating the metal, and the remaining portion combines with the oxide, forming nitrate of silver. Crystals are deposited as the solution cools; when these are fused to expel any adhering water or excess of acid, common *lunar caustic* is procured.

610. Fuse half a grain of nitrate of silver on a slip of glass, heating it by the flame of a lamp. All the nitric acid and oxygen are expelled; metallic silver alone remains.

611. Dissolve 20 grains of nitrate of silver in an ounce of water, to be used as a solution for experiments with silver. Arrange six glasses with water, adding to each a few drops of the solution of silver, and afterwards the following tests in solution:—

612. Potassa separates oxide of silver as an ash-grey powder.

613. Carbonate of potassa precipitates carbonate of silver.

614. Lime precipitates oxide of silver.

615. Hydrochloric acid, chlorine, and common salt, precipitate chloride of silver.

616. Chloride of silver is white and curdy, but assumes a dark colour on exposure to the light.

617. Put a fragment of copper into one glass, of zinc into another, and a few grains of mercury into a third; on covering each with a little of the solution of nitrate of silver, metallic silver soon appears, a corresponding quantity of the other metal which precipitates it being dissolved.

618. Write on a piece of linen with a pen dipped in the solution of the nitrate, and, when dry, immediately spread upon it a solution of potassa or soda. The oxide of silver is left insoluble upon the cloth, and soon darkens in its tint, leaving a permanent mark upon the cloth. A solution of the nitrate forms common marking ink. The alkali is used to remove the nitric acid, and prevent the cloth from being corroded. A carbonated alkali, as common soda, is often used instead of the purer alkali; 100 grains may be dissolved for this purpose in an ounce of water.

619. GOLD.—This metal is distinguished by its malleability and fine yellow colour; it is found principally in a pure form. Gold-leaf is so thin that 282,000 leaves are required to make up the thickness of an inch. In gilded silver-wire, the gold is less

than the 3,000,000th part of an inch in thickness. It is not affected by air or oxygen at any temperature, and common acids have no effect upon it.

620. Put four or five gold leaves into an evaporating basin pour upon them a few drops of nitric and of hydrochloric acids. Chlorine from the hydrochloric acid quickly dissolves the gold. Evaporate the solution to dryness, so as to expel excess of acid; terchloride of gold remains.

621. Dissolve the terchloride in 30 or 40 drops of water. Dip a slip of glass into the solution, and heat it over a lamp; the chlorine is expelled, and metallic gold remains. On looking through the glass, a purple tint is often seen. Write upon the palm of the hand with a pen dipped in a solution of the terchloride; it acquires a purplish tint, which disappears in a few days.

622. Heat a slip of glass in the flame of a lamp, touch powdered borax with it, when it immediately adheres. A drop of the solution is then to be put upon the borax, when it is to be heated by a lamp, taking care not to smoke it. A beautiful ruby-coloured compound appears; metallic gold is afterwards observed, if the heat be continued long.

623. Put three drops of the solution upon paper, and add the following tests in solution.

624. Sulphate of iron, which precipitates metallic gold of a dark colour, being in a minute state of division.

625. Hydrochlorate of tin produces a purple precipitate, containing gold and oxide of tin, and usually termed the *purple precipitate of Cassius.*

626. Hydrosulphuret of ammonia produces a dark coloured sulphuret of gold.

627. *Platinum* is a metal much prized in making crucibles, capsules, and numerous other articles of chemical apparatus, as it is scarcely affected by any ordinary chemical agent, many of which corrode other metals. It is also very infusible, not being melted by the heat of any common furnace.

628. Dissolve five or six grains of platinum wire in a drachm of nitric acid, mixed with an equal bulk of hydrochloric acid. Add more acid if it be required, and evaporate cautiously to dryness. Bichloride of platinum is obtained: dissolve it in one or two drachms of water. Add a solution of iodide of potassium to a part of it; a deep coloured compound immediately appears.

629. Add a solution of hydrochlorate of ammonia; a ternary compound of this substance and the platinum is formed, and is soon precipitated of a yellow colour. Heated to redness in a crucible, every thing is expelled except the metallic platinum.

it is not fused, but remains in minute particles, in which condition it absorbs much oxygen from the air, and when hydrogen is directed upon it, a red light is observed, and the hydrogen is soon inflamed.

ALLOYS AND AMALGAMS.

630. *Alloys* are compounds in which metallic bodies are combined solely with each other. They are formed in general by fusing the least fusible metal in the first instance, and adding the others to it. The term amalgam is usually applied to alloys containing mercury. Some alloys consist of two metals only, but in others a number are combined together.

I. *Brass* = 3 parts copper + 1 zinc.

II. *Dutch gold and pinchbeck* = copper and zinc combined in various proportions, according to the quality required.

III. *Bronze and gun-metal* = 8 or 9 parts copper + 1 tin.

IV. *Bell-metal* = 3 parts copper + 1 tin.

V. *Speculum metal* = 2 parts copper + 1 tin.

VI. *Pewter* = tin, with small portions of other metals.

VII. *Plumbers' solder* = 1 part tin + 2 lead.

VIII. *Tinfoil* = tin + a small portion of lead.

IX. *Fusible alloy* = 8 parts bismuth + 5 lead + 3 tin.

X. *Rose's fusible alloy* = 2 parts bismuth + 1 lead + 1 tin.

XI. *Gold coin* = 11 parts gold + 1 copper.

XII. *Standard silver* = 12 and 1-3d silver + 1 copper.

XIII. *Tinned iron*, or *tin plate*, consists of iron coated on the surface with tin.

631. Many metals may be coated with gold or silver by precipitating the gold and silver upon them from their solutions.

632. *Fluid amalgams* of gold and silver are used for the same purpose; they are spread upon the metals to be coated, and the mercury is expelled afterwards by heat.

633. Eight parts of the fusible alloy + 1 mercury = an amalgam which is fluid at 170 degrees.

634. *Amalgam for the electrical machine* = zinc 1 part + 1 tin + 2 mercury.

CHAPTER XXIV.

ORGANIC CHEMISTRY.

635. *Organic chemistry* signifies the chemical history of the various proximate principles which have been observed in the animal and vegetable kingdoms, and which are there associated

together so as to produce a peculiar structure, termed *organic*, such as is never seen in any of the products of the mineral kingdom. Gum, sugar, starch, woody fibre, albumen, fibrine, gelatine, and all those numerous substances of which plants and the bodies of animals are composed, constitute those proximate principles which are the products of animated nature. All of them, however, are composed principally of a very few of the same elements.

636. Vegetable substances are composed principally of carbon, oxygen, and hydrogen; nitrogen is more rarely observed in them. Animal matters consist generally of carbon, oxygen, hydrogen, and nitrogen; the presence of nitrogen gives to them many of the more peculiar properties by which they are distinguished from vegetable substances.

637. All animal and vegetable substances are decomposed by heating them in an open fire, burning as their carbon and hydrogen act freely on the oxygen of the air. They leave in general a small quantity of ash, composed either of potassa, various salts containing soda, potassa, or lime, and traces of iron or other metals.

638. The chemical changes that take place in the animal and vegetable kingdom during life, consist essentially in the transformation of part of the varied materials used as food, so that they become assimilated, and take their place as portions of the living texture, while other matters which may have already occupied a similar station are gradually removed to make way for that arrangement that may at the moment be best adapted for the living frame. Thus, a perpetual accession of new particles and removal of others proceeds steadily and uninterruptedly so long as life is sustained. The precise nature of the chemical changes that occur in most of these cases, is very obscure, and traced with much difficulty, though the general action is understood. Matters forming part of a living system, do not present the same chemical changes that are observed in dead matter; this does not arise from there being one kind of chemical action to which minerals and dead matters are subject, and another for matter endowed with life, but merely from the peculiar circumstances in which they are placed in the living system, preserving them in a particular condition, in the same manner as mineral substances may be exposed to one operation, or protected from the action of particular bodies by peculiar treatment.

639. It is curious, however, to observe how speedily any portion of animal or vegetable matter becomes subject to ordinary chemical changes when its vitality is gone, whether this may have ensued in consequence of its having been injured or removed

altogether from any connexion with the frame to which it was attached, or from the whole body having been deprived of life. A very remarkable illustration of this fact is presented in the bodies of persons or animals who may have been killed suddenly. There, the gastric juice, a peculiar fluid subservient to digestion, which affects the food only during life, instantly attacks the substance of the stomach, when life is extinct, in the same manner as it continues to affect the food itself, corroding it often to such an extent in its most depending part that it is completely perforated and destroyed by that very agent which it supplies during life for promoting digestion and the nourishment and strength of the system.

640. Again, the examination of the great changes effected within the system while the temperature is comparatively stationary, has taught chemists a very important lesson, namely, that great and new changes may probably be effected on all kinds of materials by long exposure to various carefully regulated temperatures; and in modern times, no principle has been applied with more success in preparing different compounds, and in examining generally the products of the animal, vegetable, and mineral kingdoms, than that which we have now mentioned as being dependent on the long-continued application of a fixed and carefully regulated temperature.

641. When heated in vessels so that the air is excluded from them, much carbureted hydrogen gas is evolved; water, tar, and numerous oily or resinous compounds, may also be separated by distillation, and a considerable quantity of charcoal remains. But the precise effects produced are much influenced by the exact degree of temperature to which they are subjected, so that very various products may be obtained from the same materials, according to the degree of heat applied. Changes induced by a temperature comparatively low, and without the separation of carbon, are said to be effected by the *white distillation*, the resulting products being always of a light colour, while part of them are generally converted into vapours which may be separated by distillation. Products obtained by exposing animal or vegetable matters to a high temperature, are said to be formed by *destructive* distillation; they are usually mixed with tar and carbon, which give them a dark appearance.

642. When animal or vegetable substances are combined with various chemical agents, they may be rendered much less prone to putrefaction or decay than they are under ordinary circumstances. This depends in some cases upon a combination being effected between the organic matter and the substance used, while on other occasions they appear to operate

principally by excluding the action of atmospheric air. This is particularly observed in many of the processes adopted for curing meat and preserving fruit. Occasionally, however, the principal value of some of the materials used depends on the insolubility of the compounds they form with different animal or vegetable substances that may have been fluid previously, and extremely prone to decomposition. Metallic salts have been very generally used for the purpose of preserving timber in exposed situations, among which the hydrochlorate of zinc, introduced lately by Sir W. Burnett, has been much employed; it is applied in solution, not only to wood, but also to sail-cloth, cordage, or other materials, which are steeped in the solution, and subsequently dried. Kreosote, which is powerful in coagulating numerous albuminous compounds, owes its power of preserving various animal substances to the impervious nature of the compound it forms with the albuminous fluids, which would otherwise be prone to putrefaction.

643. The entire exclusion of the air is very favourable for the preservation of numerous animal and vegetable substances from decay; which may apparently be preserved indefinitely, or at least for a series of years, without undergoing any change. This is well illustrated in the various processes introduced of late years for preserving meat, more particularly in those introduced by Mr Gillon. In the process conducted by Mr Goldner, the materials being cooked and heated at a temperature elevated moderately above 212 degrees, the atmospheric air is entirely expelled through a small aperture by the steam formed within the tin case in which they are heated, after which all communication with the external atmosphere is intercepted by closing the aperture suddenly with solder, while the steam is still escaping in full force.

644. On board ship, bread that becomes overrun with insects under ordinary circumstances, may be kept indefinitely in air-tight iron tanks without injury. And where the bread has been already injured from the cause now mentioned, the insects are soon destroyed if they be introduced into air-tight tanks, any oxygen necessarily present at first being soon consumed if they are well filled.

645. The greater number of organic products are prone to putrefaction, which proceeds most rapidly at a warm temperature, and when there is abundant access of air and moisture. Excessive heat retards or arrests it altogether by expelling moisture, and extreme cold produces the same effect by inducing congelation.

646. Many soluble matters associated with certain portions of water pass rapidly into putrefaction; but if they are rendered insoluble by the action of metallic salts, decomposition is arrested. Hydrochlorate of zinc added to such materials coagulates, and precipitates albuminous substances, decomposing also sulphureted hydrogen—an abundant source of offence in numerous cases of putrefaction. M. Ledoyen uses the nitrate of lead, and Mr Ellerman has prepared a solution containing different salts, which act on the contents of drains and cesspools in the same manner as the hydrochlorate of zinc introduced by Sir W. Burnett.

CHAPTER XXV.

VEGETABLE CHEMISTRY.

647. All seeds contain a *germ*, which produces the future plant. *Germination* is the process by which the germ begins to grow from the seed, one part, the *radiole*, descending into the earth and forming the roots, while another, the *plumule*, ascends and produces the stem. When the seed is planted, sugar is formed by the matter around the germ, constituting the first nourishment it receives. The presence of oxygen is necessary to commence germination, which cannot proceed at a great depth from the surface of the soil in which the seed is placed.

648. *Vegetation* includes all those processes which are necessary to the growth of the plant after germination. By *absorption*, nutritious matters are taken up by the roots and other parts of plants; by *circulation*, the sap is carried to the leaves, and also to each individual portion of the plant, where the different proximate principles are separated from it by the process of *secretion*. Carbon, oxygen, hydrogen, and nitrogen, are supplied by the elements of air, and by the water, ammonia, and carbonic acid associated with it. The animal and vegetable matters in many of the most valuable manures supply nitrogen and carbon more freely than they are afforded by the atmosphere alone. The mineral constituents of manures and soils assist the general fertility in proportion to the facility with which they yield potassa, soda, silica, lime, magnesia, phosphoric and sulphuric acids, and the other mineral substances that enter into the composition of vegetables. The following table gives a view of the composition of some of the more important vegetable principles, and of compounds formed *from them*:—

TABLE SHOWING THE COMPOSITION OF DIFFERENT VEGETABLE PRINCIPLES, AND OF PRODUCTS OBTAINED FROM THEM.

The figures placed under the elements named show the number of equivalents of each element in one equivalent of the compounds to which they refer.

	Oxygen.	Carbon.	Hydrogen.	Nitrogen.
Gum,	11	12	11	...
Lignine,	8	12	8	...
Gun-Cotton, 4 ; N+	8	12	8	...
Starch,	9	12	9	...
Sugar, dry,	10	12	10	...
Sugar, common,	11	12	11	...
Sugar from Starch,	14	12	14	...
Acetic Acid,	3	4	3	...
Benzoic Acid,	3	14	5	...
Citric Acid,	4	4	2	...
Cyanic Acid,	1	2	...	1
Gallic Acid,	5	7	3	...
Hydrocyanic Acid,	1	2	1	1
Malic Acid,	8	8	4	...
Succinic Acid,	3	4	2	...
Morphia,	6	34	18	1
Cinchonia,	1	20	12	1
Quina,	2	20	12	1
Strychnia,	3	30	16	1
Camphene,	...	10	8	...
Naphthaline,	...	20	8	...
Oil of Camphor,	...	10	8	...
Camphor,	1	10	8	...
Indigo Blue,	2	16	5	1
Aniline,	...	12	7	1
Nicoline,	...	10	8	1
Caffeine,	2	8	5	2
Kreosote,	2	14	9	...
Benzule,	2	14	5	...
Pyroxilic Spirit,	1	1	2	...
Aldehyde,	1	2	2	...
Alcohol,	1	2	3	...
Ether,	1	4	5	...
Hyponitrous Ether, ; N+	1	4	5	...
Acetic Ether,	2	8	8	...

CHAPTER XXVI.

VEGETABLE ACIDS AND ALKALIES.

649. *Oxalic acid* is very soluble in water; crystallises with facility when its watery solution is concentrated. It is very acid, and a virulent poison. Employed in polishing brass, and in cleaning leather. It is much used as a test of lime, forming a very insoluble compound with it. It may be obtained

from the juices of various plants, but is formed, in general, artificially by heating nitric acid with impure sugar unfit for ordinary purposes, or by heating various vegetable matters, as sawdust, with lime, to a temperature between 400 and 500 degrees, removing afterwards the lime by the action of sulphuric acid.

650. *Acetic acid* is the acid of vinegar, and is formed also in large quantity by heating wood, excluding the air; obtained from this source, it is often termed pyroligneous acid. In a concentrated form it has a very pungent and fragrant odour, and is then used for vinegarettes.

651. Take 1 ounce of vinegar by measure, mix it with a little vegetable blue, which is reddened, and add to the solution bicarbonate of potassa in fine powder till the acetic acid is neutralised, the blue tint being restored. Note the quantity of bicarbonate employed, and calculate the quantity of acetic acid in the solution, 101 grains of the bicarbonate containing a sufficient quantity of potassa to neutralise 51 of real acetic acid.

652. Acetic acid corrodes many metals; with oxide of lead it forms the acetate or sugar of lead. With oxide of copper verdigris is produced.

653. *Tartaric acid* is procured from cream of tartar. It is not volatile like the acetic acid, and is decomposed when heated. One equivalent of water is always combined with it, in the condition in which it is obtained; 75·48 grains of the crystals are always used where 66·48 of the acid are required.

654. Dissolve 75 grains of crystallised tartaric acid in a tumbler one-third full of water, and dissolve 101 grains of bicarbonate of potassa in another, adding a little sugar and ginger or cinnamon powder to the mixture, if required to communicate any flavour to it. On mixing the solutions, an effervescing draught is formed, from which the carbonic acid escapes quickly; tartrate of potassa being formed in solution, and carbonic acid gas rapidly disengaged. For an ordinary draught, half the above quantity of materials is generally employed, a few grains of acid being added in excess, to communicate an acidulous taste.

655. Add a few drops of a solution of tartaric acid to a concentrated solution of carbonate of potassa, till a neutral tartrate of potassa is formed; it is very soluble in water. Add afterwards more tartaric acid till the solution is very acid; cream of tartar (bitartrate of potassa) falls down in small crystalline grains.

656. *Citric acid* is obtained from the juice of the lime and *of the lemon.* It is soluble in water, crystallisable, easily

decomposed by heat, and, when crystallised, may be kept for any length of time, not being apt to decompose like the juice from which it is separated.

657. *Malic acid*, termed also *sorbic acid*, is found in the juice of the apple and of other vegetable fruits.

658. *Gallic acid* is obtained from gall nuts, but may be procured also from numerous other vegetable substances, as the bark of the oak and the tea leaf. It is particularly distinguished by producing with peroxide of iron, when these substances meet each other in solution, a dark-coloured compound which forms the colouring matter of common ink. The colouring matter of ink may, accordingly, be destroyed by any substance which acts either on the gallic acid or on the peroxide of iron. Acids, particularly sulphuric, nitric, hydrochloric, and oxalic acid, destroy the colour of ink by combining with the peroxide of iron and liberating the gallic acid. Alkalies remove the gallic acid, and leave the oxide of iron. A solution of gallic acid often restores faded ink by acting on the iron. Chlorine appears to act on the gallic acid and decompose it, while another portion combines with the iron. Oxalic acid, and other vegetable acids, remove the colour of ink, without destroying the texture of paper or other organic matters, in the same manner as mineral acids.

659. *Succinic acid* is procured by sublimation from amber. It is much employed, when combined with ammonia, in precipitating peroxide of iron.

660. Put 20 or 30 grains of *benzoic acid* into a Florence flask, and expose it very slowly and cautiously to the heat of a lamp; it is soon melted, and converted into vapour, condensing in beautiful crystals upon the upper part of the flask, if the heat be not too great. If a piece of thread, or any solid substance, be suspended in the interior of the flask, the crystals collect very beautifully upon it.

661. *Prussic* or *hydrocyanic acid* exists in minute quantity in a number of flowers and fruits, communicating to them a very rich and agreeable flavour, as in the flower of the hawthorn, in the peach, and in the almond. It contains no oxygen, and is composed entirely of cyanogen and hydrogen; 26·44 parts of cyanogen contain 12·24 of carbon and 14·2 of nitrogen. *Symb.* C^2N. With 1 of hydrogen, 26·44 of cyanogen produce 27·44 of prussic acid. *Symb.* HC^2N. It is distinguished by its great power, when in a concentrated form, in affecting the animal economy, a few drops being quite sufficient, when laid upon the tongue of a large dog, to produce instant death almost with the rapidity of lightning. Laurel water, noyau, and many other liquids, contain a portion, and sometimes give

rise to fatal effects, when the prussic acid is present in too large quantity.

662. No fact appears more singular at first, than that a principle of such powerful activity in reference to the animal economy, should consist of the very same elements as are consumed every day in our food; but chemistry abounds in facts such as these, as is observed, for instance, in the compounds of oxygen and nitrogen, these elements constituting in one proportion the air that we breathe, and in another the corrosive nitric acid or aquafortis.

663. Prussic acid is usually prepared from ferrocyanate of potassa, a yellow-coloured salt, which is formed on the large scale by heating animal matter with potashes and iron. This salt is mixed with half its weight of sulphuric acid, previously diluted with three or four times its bulk of water, and allowed to cool before it is poured upon the salt in powder; the acid uniting with the potassa and the prussic acid, which is united with iron in the salt, may be condensed in a receiver in combination with the water which distils along with it. The acid should be prepared only in small quantity, and always diluted with water, by those not accustomed to operate with it, so as to prevent any risk of accident. The receiver ought to be kept very cold. Five or six grains of the salt are quite sufficient to give enough of the diluted acid to allow its flavour, so similar to that of the hawthorn, to be recognised.

664. As a chemical agent, hydrocyanic acid is extremely feeble, and very prone to decomposition. Strong and pure acid begins to be decomposed when subjected to the action of light, and, in warm weather, very soon after it has been prepared.

665. To detect hydrocyanic acid in fluids suspected to contain it, the following process may be adopted. Distil the suspected liquid, after adding a little acetic acid to combine with any alkali that may be present. Add to the product salts containing the oxide and peroxide of iron; liberate these oxides by the addition of potassa, when prussian blue is formed, if prussic acid be present. A few drops of hydrochloric acid render the blue more distinct, by dissolving any excess of oxide of iron.

666. *Cyanogen* may be procured by heating the bicyanide of mercury in a glass or iron tube. It is a pungent suffocating gas, very inflammable, and burns with a purple-coloured flame.

667. *Cyanic acid* is composed of cyanogen and oxygen.

668. *Fulminic acid* is considered isomeric with cyanic acid. It is formed when silver or mercury is dissolved in nitric acid, and mixed subsequently, while still warm, with alcohol. The

nitrogen and oxygen are supplied by the acid, and the carbon by the alcohol. The fulminic acid forms insoluble compounds with silver and mercury, which explode with great violence when heated, and also by friction or percussion. They ought to be prepared only in very small quantities at a time, and with the utmost caution.

669. *Vegetable alkalies.*—A number of compounds called vegetable alkalies, have been discovered in many of the more important medicinal substances obtained from the vegetable kingdom; in these the medicinal properties of the substances from which they are extracted are found more particularly to reside. *Morphia* is the name of the most important vegetable alkali procured from opium. *Quina* and *cinchonia* are procured from Peruvian bark. *Strychnia* is obtained from *nux vomica*, and *veratria* from *white hellebore*. All these substances, and many others, are termed vegetable alkalies, and sometimes alkaloids, as they combine with acids, neutralise them, and form salts, in the same manner as other alkalies. They are composed of the usual elements of vegetable matter, but contain also a considerable quantity of nitrogen.

CHAPTER XXVII.

OILY AND RESINOUS SUBSTANCES.

670. All oily and resinous substances are composed, in general, of about 80 per cent. of carbon, 11 or 12 of hydrogen, and 8 or 9 of oxygen; some contain no oxygen, as camphene, commonly called the spirit of turpentine. Exposed to the air, on any extensive surface, they are apt to imbibe oxygen slowly; and some fixed oils, even at natural temperatures, gradually become warm under these circumstances, and burst ultimately into flame, sometimes in a few days, but often not till weeks or months have elapsed. Numerous fires have been traced to the spontaneous inflammation of oil spread upon tow or cotton.

671. *Volatile oils* rise in vapour at the temperature of boiling water; they burn in general with much smoke, and are easily inflamed.

672. Put an ounce of cinnamon bark in fragments into a retort; cover it with water, and distil a portion of the water into a receiver; a portion of volatile oil, having the odour of the cinnamon bark, rises along with it, and renders it milky as it condenses in the receiver.

673. Pour a few drops of oil of turpentine upon a piece

of paper, and heat it gently before the fire, or over a lamp, at a distance from the flame. It is soon entirely dissipated, leaving no greasy stain upon the paper.

674. Dip a piece of paper in oil of turpentine, put upon it a grain of chlorate of potassa in powder, and touch it with a drop of aqueous sulphuric acid; peroxide of chlorine is immediately liberated, and inflames the turpentine.

675. Put two drachms by measure of oil of turpentine into any cup or basin placed in the open air, or at a large ventilator. Put into a glass, tied to the end of a long stick, four drachms by measure of strong aqueous nitric acid and one of aqueous sulphuric acid, taking care that there is no turpentine in the measure employed. Hold the mixture as far away from the face as can be done conveniently, and pour it upon the oil of turpentine; much oxygen is immediately communicated to it, and the turpentine is inflamed with explosive violence.

676. *Fixed oils* are frequently obtained by expression; they are thicker than volatile oils, and unctuous to the touch, and require a temperature about 600 degrees to convert them into vapour. They may be regarded generally as compounds of two principles, *Elain*, or the more fluid portion, and *Stearin*, the more solid part, which freezes in cold weather before the elain. When the oil is boiled with potassa or soda in solution, soap is formed, and a substance having a sweet taste is separated, which is usually termed *glycerine*.

677. Heat a few drops of any fixed oil upon paper; it is not volatilised except by a heat sufficient to decompose the paper.

678. Boil soft soap in twice its bulk of spirit of wine, filtering the solution if it be not transparent.

679. Add a portion to common water; if very pure, only a slight opalescence is observed.

680. Add a little of the solution of hydrochlorate or sulphate of lime to water, and mix with it a portion of the solution of soap; the acid unites with the alkali of the soap, and remains in solution, a curdy precipitate, consisting of the earthy and oily matter of the soap, is separated.

681. To another solution of the hydrochlorate or sulphate of lime, as in 680, add carbonate of potassa, or of soda, so long as any precipitate is formed. The acid of the earthy salt unites with the alkali of the carbonate, and the lime and carbonic acid fall down as an insoluble carbonate. Add the solution of soap to the liquid in this condition; it is not decomposed; the acid of the earthy salt is already combined with alkali, and the earthy matter has been precipitated, so as to be incapable of affecting the oily or fatty matter.

682. Dissolve 10 or 20 grains of *resin* in three or four times

its bulk of alcohol. Pour the solution into a large quantity of water; the alcohol unites with the water, and the resin is separated.

683. Perform a similar experiment with *camphor*.

684. Heat a few grains of camphor in a tube by a small lamp. It soon melts, and is then volatilised, condensing in a solid form in the upper part of the tube.

685. Put an ounce of *wax* into a small cup or evaporating basin; melt it by placing the cup in boiling water. Untwist a piece of cord, and dip the separate parts into the wax; cut them into lengths of 6 or 8 inches, to be used as matches in applying a light in chemical experiments.

686. *Benzule* is the name applied to a compound which forms the basis of several vegetable substances. Benzoic acid is a compound of benzule and oxygen. *Balsams* are viscid liquids or solids procured from different vegetables.

687. *Amber* is considered to have been a balsam originally, and to have assumed subsequently its ordinary form.

688. *Gum resins* are concreted vegetable juices, such as gamboge and guaiac, which contain various vegetable principles.

689. *Caoutchouc*, or *India rubber*, is the concrete juice of the *ficus elastica* and some other trees. It is soluble in spirit of turpentine, naphtha, ether, and in tne fluid it affords by destructive distillation. Its solution, thickened and made to resemble a paste, is much used in the preparation of waterproof cloth and flexible tubes.

690. *Gutta Percha* is another concreted juice, approaching to India rubber in many of its properties, and much prized for its toughness, tenacity, and flexibility.

PRODUCTS OF DESTRUCTIVE DISTILLATION.

691. Vegetable or animal substances heated to a high temperature, all air being excluded, produce a great variety of compounds, solid, liquid, and gaseous, fixed and volatile. *Wood tar* is a mixture of numerous oily products with water, acetic acid, and resin. *Coal tar* is similar in many of its properties, but the water it contains abounds in ammonia, and not in acetic acid. *Pitch* is the name given to the impure resin that remains when tar is heated, till water, and all other matters not oily or resinous, are expelled. Its consistency depends on the extent to which it is heated, and the nature of the oils separated. *Asphalte*, *mineral pitch*, and *petroleum*, resemble pitch and other compounds that may be obtained from tar.

692. *Naphtha* is the name given to the oily fluid obtained by distillation from coal tar. It contains various distinct compounds, some of which, as *aniline*, have been the subject of minute investigation. Napthaline is an inflammable crystallisable solid, which is also procured from coal tar.

693. *Gun cotton* is a compound of lignin and nitric acid. It is prepared by dipping cotton in this acid, after which it is washed and dried. The oxygen of the nitric acid sustains the rapid and explosive combustion of the cotton when it is ignited.

694. *Pyroxilic spirit* is one of the products obtained by the destructive distillation of wood. It is often used as a substitute for alcohol in spirit lamps. It has a peculiar odour, and burns with a smokeless flame.

695. *Paraffine* is an inflammable solid, which has been procured by distillation from the tar of beechwood, and from certain varieties of petroleum. It is white, tasteless, inodorous, soluble in alcohol, turpentine, and naphtha. It burns brilliantly, and without smoke, and is not decomposed by the action of acids, alkalies, and other powerful chemical agents.

696. *Eupion* is the name given to a volatile oil which is obtained by distillation from the tar of animal matters.

697. *Kreosote* is a volatile liquid which has been obtained both from wood and coal tar. Its more characteristic property is its power in coagulating albumen. Its odour is similar to smoked meat, in which the kreosote is considered to form a compound with the albuminous materials. It is soluble in alcohol, ether, naphtha, and acetic acid. Water mixed with it acquires its taste and odour. In a concentrated form, it is used in toothache, coagulating albuminous substances, and protecting the nerve from the immediate action of the air, by the dense compounds formed upon it.

CHAPTER XXVIII.

LIGNIN, GUM, STARCH, AND GLUTEN.

698. *Lignin* is the term applied to woody fibre. It is composed of the usual elements of vegetable matter, but contains also minute quantities of potassa and various salts. It is particularly distinguished by its insolubility in water, alcohol, and many other chemical agents.

699. *Gum* is a term applied to several vegetable products, of *which gum-arabic* is the most important. Dissolve gum-arabic

in water, after reducing it to powder, placing it in a flask or cup heated by immersing it in boiling water. Mix a portion of the solution with an equal bulk of alcohol; the water unites with the alcohol, and the gum is separated.

700. *Cherry-tree gum* is similar in many respects to gum-arabic, but is insoluble in cold water.

701. *Tannin* or *Tannic Acid*, is found abundantly in the vegetable kingdom. It is solid, has an astringent taste, is colourless and inodorous, is soluble in water, alcohol, and ether, and gives a bluish-black precipitate with salts of iron. It is particularly distinguished by precipitating gelatine.

702. *Vegetable albumen* resembles animal albumen, and is coagulated by heat.

703. Rasp several potatoes in a basin, add water, and stir the mixture; the *starch* which they contain is deposited, being insoluble in cold water. (See 465.)

704. Mix starch with cold water, and pour boiling water upon it till a strong gelatinous mass is formed. *Sago, tapioca, arrow-root,* and *potato flour,* are all composed of starch.

705. Mix a tablespoonful of wheaten flour with water, so as to produce a stiff dough. Spread it upon the palm of the left hand, hold it over a basin of cold water, and with the right hand pour water upon it so long as a milky fluid appears exuding from it, pressing it gently from time to time with the finger. Flour consists principally of starch and gluten mixed with gum and sugar. The water dissolves the gum and sugar; the starch is carried away mechanically suspended by the water, and *gluten* remains on the hand. If the flour be of good quality, about one-third of its weight of gluten is usually obtained. Flour is often sold of such indifferent quality that little gluten is procured from it. Gluten is the most nutritious part of flour, and forms the numerous little cells that appear in fermented bread, as gas and vapour rise in the substance of the dough. It contains nitrogen along with carbon, oxygen, and hydrogen, resembling animal matter in its composition.

CHAPTER XXIX.

VEGETABLE COLOURING MATTER.

706. Numerous proximate principles are familiarly known, which are particularly distinguished by their colour. Each of these is to be regarded as a distinct compound, of which its peculiar colour is only one of numerous properties which it may present. It is accordingly subject to all the usual chemical changes of which colouring matter is susceptible. It may be separated from other materials; it may be decomposed, and deprived consequently of its colour; it may be formed again by new arrangements in some cases, when its colour is restored; it may be combined chemically with various bodies, acquiring a new colour, or becoming colourless, according to the nature of the substance with which it is associated.

707. The art of *bleaching* consists in depriving the substances that are bleached of any colour that they may possess, and also of any impurities with which they may be stained. Chlorine, acids, and alkalies, are the principal agents used for this purpose, the former destroying all animal and vegetable colouring matter, while the others, from their extensive chemical agency, act powerfully upon numerous substances that may be associated with them.

708. The art of dyeing consists in communicating to cloth or other substances the various tints that may be required, and is founded upon the chemical attraction that subsists between colouring matters and those to which they are applied. Some colouring matters, as indigo, if merely dissolved, and brought in contact when in solution with cloth, leave the materials composing the solution, and combine with the cloth; such colouring matters have a strong attraction for cloth, and are usually termed *substantive colouring matters*. Others, again, having a feeble attraction for cloth, may still be combined with it in a comparatively permanent manner by the addition of various metallic oxides, earths, or other chemical agents; all of which unite together so as to form one compound. In such cases the chemical agent employed, which is usually termed a *mordant* or *basis*, is combined with the cloth before the colouring matter is applied; colouring matters used in this manner are usually termed *adjective colouring matters*.

709. *Calico-printing* is a kind of topical dyeing, by which the colouring matter, or the mordant that fixes it, or both, are applied only to certain parts of the cloth, so as to present a *pattern*. Sometimes wooden blocks, having patterns cut on

them, are used for this purpose; these being applied with a light touch to a thick mixture of the materials used, so that they are received by the pattern in the same manner as ink is received by types. On other occasions, the whole cloth is dyed in the first instance, and a white figure produced subsequently by applying the pattern after it shall have received any materials that must decompose, dissolve, or withdraw the colouring matter wherever it touches the cloth. If the mordant be withdrawn by any other chemical agent, that alone is sufficient to enable the colouring matter to be discharged with facility.

710. *Chromule* is a term applied to various coloured principles that may be obtained from the leaves and flowers of plants.

711. *Chlorophyle* is the term applied to the green colouring matter of the leaves of plants.

712. *Chromogen* signifies a matter that has no colour in itself, but which may still be considered as a basis of colouring matter, as, by the action of other bodies, colour may be developed in it. If water containing sulphurous acid be added to the colouring matter of common coloured cabbage in solution, it decomposes it, and a colourless compound results. The colouring matter is reduced to the state of *a chromogen*. But if a portion of the colourless compound be mixed with a little sulphuric acid, a brilliant red tint appears. If ammonia, or any other common alkali, be added to a second portion of the colourless liquid, a fine green appears.

713. *Erithrogen* is the term applied to that variety of chromogen which becomes red with acids. The term *xanthogen* is applied to those that become yellow by the action of alkalies.

714. Cut a common red cabbage into small pieces, and boil it for a short time with no more water than is required to cover it. Use the solution procured in this manner, or by simply infusing the cut cabbage in boiling water, as the *cabbage* or *vegetable blue* so often referred to in the preceding pages.

715. Dip into the solution a number of slips of paper, four or six inches square; keep them there till they imbibe some colouring matter, and then dry them, excluding them afterwards from the action of the light, until they are required for use. Cut off small slips, which may be touched with a minute quantity of any solution, to be tested so as to indicate the presence of acid or alkali, as they are reddened by one, and turned to a green by the other.

716. Dilute a solution of the vegetable blue, and try alternately the action of acids and alkalies upon it. Acids render it red; alkalies turn it to a green.

717. Boil litmus in five or six times its bulk of water; pre-

pare test papers with the solution as in 715. They are reddened by acids, but not turned to a green by alkalies.

718. Pour upon a table-spoonful of turmeric placed upon a common plate three or four times its bulk of boiling water, and prepare turmeric test papers as in 715. They are of a fine yellow, and become reddish-brown by alkalies, but are not affected by acids.

719. Add a little alum in solution to a dilute solution of litmus in a jar or flask; mix a little potassa with the liquid till the alumina appears, which combines with the colouring matter as it is precipitated.

720. Dip a piece of cotton cloth into a diluted solution of sulphate of iron, and allow it to dry; immerse it afterwards in an infusion of galls, containing gallic acid; it unites with the iron, and the cloth is dyed of a bluish-black colour.

721. Mix a little of the solution of the sulphate of iron with paste, spread it very thin upon cloth, and take up a little by pressing upon it any stamp or block of wood with a pattern cut upon it, which may be applied many successive times to different parts of the cloth if required; any plain piece of wood will do, if no pattern can be made. Dry it, immerse it in a little aqueous ammonia diluted with much water; the acid is removed, and the pattern appears on the cloth in the form of oxide of iron. Run a little water upon it, and pour upon one portion the infusion of galls. A black pattern is now seen upon a white ground. Put another portion into a basin of water, to which a few drops of ferro-cyanate of potassa in solution and aqueous nitric acid shall have been added. A blue pattern is now observed.

722. Put a number of flowers of any colour, and also several green leaves, into a vase of chlorine; all of them are quickly blanched.

723. Put a hank of unbleached yarn, and a number of stripe of different coloured cloths, dyed with animal or vegetable colouring matter, into a solution of chlorine in water. They are all soon bleached by the powerful action of the chlorine. Similar experiments may be tried by adding a solution of chlorine to solutions of colouring matter in water. Chloride of lime dissolved in water may be substituted for chlorine, adding a few drops of acid.

724. Put several flowers into a large glass jar, and inflame a little sulphur in a small metallic cup placed within the jar. The sulphurous acid produced by the combustion of the sulphur blanches a number of flowers. The purple grape hyacinth, the blue crocus, the violet, and many other blue flowers, do well for this experiment; the first is the best.

725. Hold some of the blanched flowers in vapours of hydrochloric acid gas, produced by pouring aqueous sulphuric acid on common salt; the acid, acting on the base of the colouring matter, produces a red tint.

726. Put another portion of the blanched flowers into a jar containing a very little strong aqueous ammonia; the vapour escaping from it turns them to a fine green.

CHAPTER XXX.

SUGAR.—VINOUS FERMENTATION.—ALCOHOL.—ETHER.

727. Sugar is a vegetable principle which is capable of affording a great diversity of products, more particularly when subjected to those changes that accompany the vinous fermentation, a process that consists essentially in the decomposition of sugar, and in the production of alcohol and carbonic acid.

728. *Sugar* is solid, white, and inodorous when pure, and does not deliquesce on exposure to the air. It is soluble in water and alcohol, and combines with alkalies, earths, and metallic oxides. By the strong acids it is decomposed. Sugar is procured principally from the juice of the sugar-cane, which may be regarded as an impure solution of sugar. Acids which it contains are neutralised by lime, and numerous impurities are removed as the juice is boiled. The solution, after concentration, gives raw sugar on cooling, from which the concentrated syrup termed *molasses* is then drained. By repeated solution, filtration, and crystallisation, the sugar is ultimately rendered of a pure white colour; animal charcoal is employed to a great extent in this process to destroy colouring matters, and albumen to coagulate and entangle impurities.

729. Sugar presents a great variety of appearances in its raw state, according to the strength and purity of the solution from which it is deposited. Its texture and appearance also are very various when fused, crystallised slowly, or combined with various proportions of water, colouring matter, or other materials.

730. Vinous Fermentation.—The term fermentation is used generally to signify any of those changes that are induced spontaneously in animal or vegetable matters by the reaction of their elements, and vinous fermentation constitutes that variety in which alcohol is produced by the decomposition of sugar. Vegetable juices containing sugar, or a solution of pure sugar in water, when exposed to a temperature between 60 and 70

degrees, soon undergo the vinous fermentation, on the addition of yeast. This is the flocculent matter that is formed during vinous fermentation, and is particularly distinguished by its power of promoting it.

731. During vinous fermentation, every 45 grains of sugar decomposed give (omitting fractions) 22 of carbonic acid and 23 of alcohol. In numerous instances the fermentation is checked before all the sugar is decomposed, and then a sweet compound is produced, which varies in its qualities according to the amount of carbonic acid retained, and the variety of mucilaginous and other matters that may be associated with the alcohol and water of the original juice or solution employed, more particularly volatile oils, astringent matter, and colouring matter.

732. The stronger wines have been said to contain 25 per cent. of alcohol, and others from 12 to 18, while ale, porter, cider, and perry, contain from 4 to 10 per cent. These estimates are now considered to be rather high, according to some recent experiments.

733. *Alcohol* is a transparent, colourless liquid. It boils at 173·5, when its specific gravity is ·810. It is inflammable, and burns with a pale flame; the products of combustion are water and carbonic acid. It dissolves numerous salts, and also resins, camphor, and volatile oils. It combines with water in every proportion, and the amount associated with it is estimated by ascertaining its specific gravity; the less its specific gravity, the smaller is the proportion of water combined with it. In purchasing alcohol for experimental purposes, its specific gravity should be carefully ascertained; or it may be mixed in a phial with dry carbonate of potassa, which falls without being dissolved.

734. Alcohol is prepared by distillation from wine, ale, porter, the fermented infusion of malt, or other materials prepared expressly for affording this substance in a concentrated form. Brandy is the product obtained from wine, whisky from the fermented infusion of malt, and rum from the fluid obtained by the fermentation of molasses.

735. From these distilled liquids a stronger spirit, termed *spirit of wine*, is prepared by a second distillation, and *rectified spirit of wine* is usually the product of a third distillation. Alcohol, or *spirit absolutely free from water*, is procured by treating common alcohol with chloride of calcium, lime, or other materials which have a powerful attraction for water, separating the alcohol carefully by distillation.

736. *Ethers* are very volatile, inflammable, and fragrant compounds, which are usually obtained by the action of acids

with alcohol. Sulphuric ether is formed by mixing equal weights of sulphuric acid and alcohol, when the ether is formed on the application of heat, and may be separated by distillation. Nitric, called also hyponitrous ether, may be formed on the same principle; but the materials must be mingled with extreme precaution, and by peculiar arrangements, otherwise violent and dangerous explosions are apt to take place.

737. *Aldehyde* is the term applied to a compound obtained from alcohol, by removing part of the hydrogen which it contains.

CHAPTER XXXI.

ANIMAL CHEMISTRY.

738. In the animal kingdom, the chemical changes that ensue during life are in general more complex than those observed in the vegetable kingdom. This arises from the more elaborate organisation observed in the bodies of animals, and the abundance of nitrogen.

739. From the blood, according to the structure of the various organs or tissues to which it is carried, each selects that portion which is required to sustain its functions, producing thereby a series of chemical changes, and returning at the same time by the blood-vessels, or by another peculiar series of vessels termed absorbents, the waste or debris produced in each particular place.

740. This waste or debris is in its turn again cast off from the blood, every portion of the system being in a constant state of decay and renovation during the whole period of existence.

741. While incessant changes advance in the materials composing the living frame, the progress of investigation is daily strengthening the opinion that electric currents pervade the whole system, and reciprocally affect and are affected by all chemical changes that take place in the body during life. Much interesting evidence has also been adduced to prove that the electric power may be the medium or instrument by which sensations are transmitted to the sensorium, and communications established between the brain and all other parts of the body, through the medium of the nerves. No plausible conjecture, however, much less any practical evidence, has been adduced as to the manner in which we become sensible of the operations going on in our own system, though the body during life has been, not inaptly, compared to a country intersected and traversed at every point by electric telegraphs, the living soul being the observer that works the telegraph,

and the brain the station-house in which his operations are carried on.

742. During *digestion*, the food mixed with saliva, other animal fluids, and with oxygen from the air, undergoes an intestine change, and gradually assumes the consistence of a pulp, when it is termed *chyme*. It was considered that a peculiar fluid—the *gastric juice*, or a substance in it termed *pepsine*—produced this change; but many concurring causes are requisite to effect it, of which the action of the fluids in the stomach form a most important part. The chyme is subjected subsequently to the action of the bile, and innumerable vessels called lacteals, whose mouths open on the interior surface of the intestines, and remove a milky fluid, which is finally conveyed to the blood before it proceeds to the lungs.

743. *Respiration* consists in the inspiration and expiration of air, the fresh air descending by a species of diffusive power into the minute vesicles in which the branches of the windpipe finally terminate, while a corresponding portion of air that has already acted on the blood in these vesicles escapes. The air does not come into direct contact with the blood, but reaches it through a membrane sufficiently strong to retain the blood, but sufficiently porous to admit oxygen to pass into the blood, and carbonic acid gas to escape. The dark purple blood returned from all parts of the body by the veins now becomes brightly red, and is conveyed to the heart, to be distributed again to every part of the frame by the arteries. In the smaller branches of the arteries, termed the extreme capillaries, the blood becomes purple as it conveys nourishment and support to each portion of the body, and it is here considered to acquire that carbonic acid which is subsequently evolved in the lungs. Whatever other changes may accompany respiration, the prominent feature is, the absorption of oxygen in the lungs, and the evolution of a corresponding quantity of carbonic acid; this operation is regarded as the great source of *animal heat*.

744. The insensible *transpiration* that proceeds through innumerable apertures at the surface of the skin, is accompanied by the evolution of carbonic acid, as in respiration. In both cases, moisture is exhaled along with the acid gas.

745. Watch the number of expirations by examining the heaving of the chest, or the moisture condensed on a plate of cold glass; they vary from 16 to 20 or upwards per minute, and may therefore be estimated on an average of from 960 to 1200 per hour.

746. Blow through a glass tube into water tinged with litmus; the carbonic acid reddens the litmus. Blow in the

same manner into lime water; carbonate of lime is quickly deposited. Blow into a small flask with a tube, expelling as much air as possible from the lungs, and immediately introduce a lighted candle suspended by a wire; it is extinguished.

747. The *blood* of the higher classes of animals consists essentially of a transparent fluid, in which red globules are observed; they are composed principally of fibrine and colouring matter. On being drawn from the body, the red globules separate from this fluid (called *serum*), and appear finally in the more solid portion, termed the *crassamentum* or *clot*.

748. *Fibrine* is the solid that forms the basis of muscular fibre, and is obtained most easily from the solid portion of coagulated blood, by washing it with water till all colouring matter is removed. It is insoluble in water and alcohol. *Albumen* constitutes the principal animal matter in the serum of the blood and in the white of the egg; it is coagulated by heat, numerous acids, and alcohol.

749. *Gelatine* is particularly distinguished by its solubility in cold or boiling water, and the insoluble compound it forms with tannin. Leather is a compound of tannin and gelatine. Glue, size, and isinglass are composed of gelatine. *Caseine* is obtained from milk, and resembles the three preceding compounds in its composition.

750. *Kreatine* and *kreatinine* are compounds which have been extracted from the juice of flesh and other animal products. *Lactic acid* is found associated with many animal substances; it received its name in consequence of having been procured at first from milk.

751. *Animal oils* and *fats*, including butter, are analogous in composition and properties to those obtained from the vegetable kingdom. In the condition in which they are usually met with, they may be regarded as fatty acids, associated with small portions of glycerine or other animal matters. From these they may be separated in general by combination with an alkali, removing the alkali afterwards by the addition of sulphuric acid. Soaps consist of these acids and alkalies.

752. *Milk* contains caseine, albumen, a peculiar saccharine matter termed lactine, and saline compounds, in addition to the oily matter associated with it. These constitute from ten to twenty per cent. of different kinds of milk, the remaining portion being water.

753. *Bile* contains a great variety of substances, and the most essential ingredient is regarded as a compound of a fatty acid and soda.

754. *Bones* are composed principally of earthy matter, consisting almost entirely of phosphate of lime, and may be pro-

cured by burning the bone in an open fire. If heated where the air is excluded, the earthy matter is left black, constituting in this condition the mixture usually termed *animal charcoal.* The charcoal is derived from the decomposed animal matter. If bone be placed in diluted muriatic acid, the earthy matter is slowly dissolved, the animal matter being left.

755. After death, a series of chemical changes ensue in animal substances, during which numerous offensive gases and deleterious compounds are evolved. They are prone to induce disease by their action on the blood; they are deficient in oxygen, and are rendered innoxious when freely oxidated by the air, or absorbed by growing vegetables. *Adipocire* is an imperfect saponaceous compound, formed when different animal matters are long exposed to the action of water.

756. Numerous sanitary measures depend on the removal of decayed animal and vegetable matter in a state of putrefaction. *Interments* in towns and in or below churches have often constituted one of the most oppressive sources of disease and death, and are interdicted in numerous places abroad.

757. Lime, chloride of lime, muriate of zinc, and many other materials, are applied to special sources of noxious emanations, with the view of counteracting their bad effects. When old drains or cesspools are opened, a fire should be kindled, to which all noxious emanations may be led and consumed.

CHAPTER XXXII.

FLAT GLASS, TUBE, AND BLOWPIPE APPARATUS.

758. When slips of glaziers' window-glass are properly selected, they may be used for the following purposes:—

759. I. *Solution.*—Broad slips of the size seen in figs. 85 and 86, or twice the length and breadth seen there, are best adapted for this purpose; they are held by one extremity, and

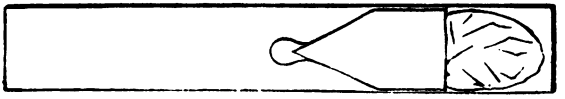
Fig. 85.

a minute quantity of the substance to be dissolved, about the size of a mustard seed, is placed at the other, covering it with eight or ten drops of the liquid used for solution.

760. II. *Boiling liquids.*—Slips of the same size as fig. 85 may be employed, but they ought to be selected as thin as

possible; those which are about the 20th of an inch in thickness do well. The part heated should be covered for the length of an inch or two with the liquid to be evaporated; the slip may be placed before the fire, in a current of warm air, or one or two inches above the flame of a very small lamp or candle.

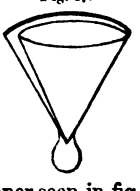
Fig. 86.



761. III. *Crystallisation.*—Solutions to be crystallised may be spread over the greater part of the glass, and left to evaporate spontaneously, or concentrated by heating, removing the slip from the heat the moment any solid appears on the edges; if the heat be continued longer, a confused mass is generally observed instead of crystals: fig. 85 represents the appearance frequently seen, where small needle-like crystals are produced. Glauber salts (sulphate of soda), oxalic acid, hydrochlorate of strontia, and bichloride of mercury, give solutions which crystallise with great facility.

762. IV. *Filtration.*—When a solution is turbid, from the admixture of solid matter, it should be collected at one extremity; a small tapered piece of bibulous or filtering paper, is then placed next it, as in fig. 86, when the fluid in general passes along, and a drop of clear fluid is obtained at the pointed extremity of the paper. The glass slip should be gently inclined, and more water or other solvent should be added, if there be not enough to moisten the paper. When the solution does not filter readily in this manner, a square piece of paper may be folded in two, this being again repeated, so that on opening it in the manner seen in fig. 87, the fluid may be poured into it as it rests on the side of the flat glass.

Fig. 87.



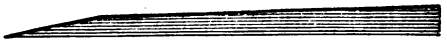
763. V. *Distillation.*—In a few cases, if a very cold slip of glass be held above a fluid evaporating steadily on another slip, part of the vapour may be condensed and retained on the cold slip.

764. These slips, or the narrow slip represented in the following figure, may also be used for *precipitation.*

765. VI. *Slips* for *testing, stirring,* and *lifting fluids.*—These are made of the form and size shown in fig. 88. Dipped into any solution, a portion adheres to the extremity; it may then

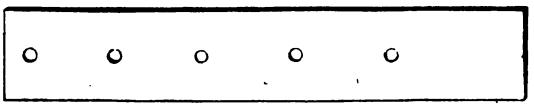
be divided into many small portions, upon a broad slip of glass or paper, by touching it with the end of the slip to which the

Fig. 88.



fluid adheres. The narrow slips being cleaned in a basin of water, may then be dipped into any tests, and applied to each separate portion distributed over the glass or paper, as in fig. 89.

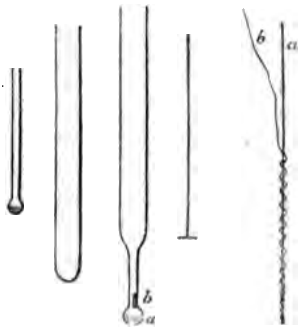
Fig. 89.



766. VII. For *fusion* and *decomposition*, the broad slips may be employed where an intense heat is not required. In examining the effect of heat where a more elevated temperature is necessary, the narrow slip should be employed, and no more taken up than can be lifted by the point, the quantity not exceeding in bulk the head of a small pin. Practise experiments of this kind with acetate of lead, red lead, sulphate of copper, sulphate of iron, nitrate of silver, terchloride of gold, and any other substances the effect of heat upon which has already been described.

767. In experimenting with borax and metallic oxides or other substances, heat the pointed extremity for half a minute, dip it instantly into powdered borax, a portion of which immediately adheres; it is then brought in contact with the substance to be fused along with it, moistening it, if this be necessary, to make a little adhere. The material is usually heated in the flame of a lamp or candle; in the outer flame, *a*, *a*, fig. 41, hot air acts upon it, but in the inner flame it is subjected to the action of hot carbon and hydrogen.

Fig. 90.



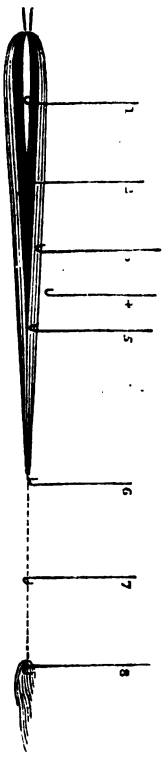
768. When minute portions of different substances are obtained in the course of blow-*pipe or* flat-glass experiments, it is often required to heat them

in tubes with solids or liquids. In such cases, small tubes made of very hard glass, and of the size seen in fig. 90, are desirable. The tube *a b* indicates a mixture at *a*, introduced with the assistance of the platinum wire *a*, around which a common thread *b* is twisted, that the neck of the tube may afterwards be well cleaned. Similar tubes and wires are used in cases where minute portions of matter are to be fused or volatilised.

769. Fig. 91 represents a blowpipe made of tin, with a brass nozzle inserted at the lower extremity. The upper part of the tube, into which air is blown by the mouth, is 3-10ths of an inch in diameter, the lower part an inch, and the nozzle, which proceeds from it, and is inserted into the flame of a candle, or of an oil, tallow, or gas lamp, terminates in an opening about 1-40th of an inch in diameter. By blowing through this tube, when the nozzle is held in any flame, it may be made to produce a conical flame, or *blowpipe dart*, as it is frequently termed, with which numerous experiments may be performed, where small portions of matter are subjected to its influence. The outer part of the flame abounds in oxygen derived from the air, and is termed the *oxidating flame;* the inner part, when yellow, and loaded with hydrogen and carbon, is termed the *deoxidating flame*. The carbon and hydrogen tend to remove oxygen. The blowpipe may be made ten inches long. Fig. 92 illustrates the more important points to which the student should attend at first, in examining minutely the nature of the blowpipe flame. He will proceed most satisfactorily by heating a small platinum hook, which may be used for lifting and exposing to heat numerous substances that may be melted upon it.

Fig. 91.

Fig. 92.



1. Points out an interior oxidating cone, so small that it is scarcely noticed under ordinary circumstances, and formed by air proceeding directly from the blowpipe.

2. The blue flame, which becomes highly deoxidating when it passes into a very luminous and carbonaceous flame.

3. Shows the outer flame, which consists principally of products of combustion.

4. Hot air beyond the outer flame, which is highly oxidating.

5. The point of greatest heat.

6. The termination of the visible flame.

7. Hot products of combustion, oxidating or not, according to the air mixed with them.

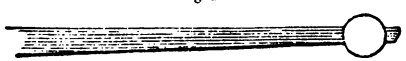
8. A point at a certain distance from the visible flame, at and beyond which an oxidating effect is always to be observed.

If a salt containing soda be made to adhere to the platinum wire, it presents the appearance seen at 8.

770. By blowing with the cheeks distended like a trumpeter's, and endeavouring to renew the blast as speedily as possible when it intermits during inspiration, the habit of keeping up a continued blast is acquired, the air with which the cavity of the mouth is filled being used to maintain the stream, while a fresh portion passes down by the nostrils to the lungs.

771. When a metal is to be procured from an oxide, or any deoxidating effect to be produced, a charcoal support is used; a piece of wood heated at one end in the fire so as to become black, does very well. Red oxide of lead, and aqueous sulphate of copper, are much used in practising the extraction of metals by the blowpipe. If the outer flame is to be used, a slip of glass, with a small earthen cup at one extremity (fig. 93) is the most convenient support; if the extremity be touched

Fig. 93.

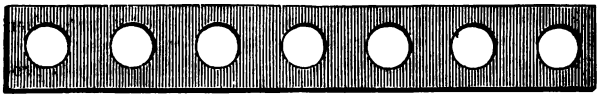


with a minute quantity of a solution of silicated potassa, it adheres firmly, and any substance placed upon it may be exposed with great facility to the action of the outer flame, and all the effects produced and seen with great distinctness.

772. These *blowpipe cups* are prepared in the following manner. Procure a piece of brass, one-twentieth of an inch thick, of the size shown in fig. 94, and with seven round holes in it. Place it upon a slip of paper, and fill up the apertures with pipe-clay, previously mixed with water, and having the

consistency of dough. Remove any superfluous clay with the finger; then press them with the finger, the brass mould and

Fig. 94.



paper resting on the left hand, so as to give them a cupped form. Dry them slowly before the fire for an hour or two, and heat them to redness in a crucible to make them fit for use.

773. Heat iron, lead, copper, zinc, tin, bismuth, and antimony, on these cups, in the outer flame, and compare the

Fig. 95.

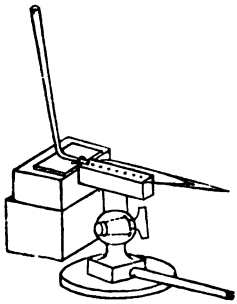


Fig. 96.

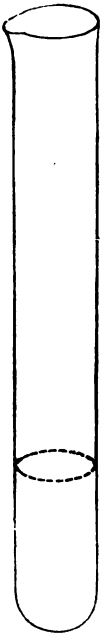


Fig. 99.

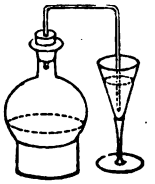


Fig. 98.

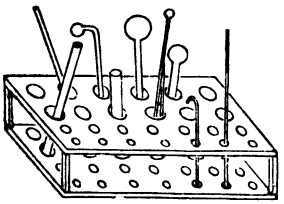
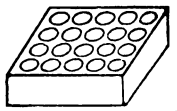


Fig. 97.



effect produced with what is observed when they are heated on charcoal.

774. Fuse a little borax on several cups, using it alone on one, and touching the others with a little of each of the following substances:—Binoxide of copper gives a green glass; metallic copper is seen in the inner flame. Binoxide of manganese produces an amethystine tint. Arsenuret of cobalt (common ore of cobalt), mixed with an equal weight of nitre, produces a fine blue. Try also the borax on the cups, after touching it with a solution of gold. A ruby-coloured compound is formed.

775. Fig. 95 shows another form of the common blowpipe, fixed to a small plate of lead, so that its motion can be regulated by the mouth, and the hands left free for experimenting. A form of gas-burner is represented there, which is much employed in blowpipe experiments. The jet represented in fig. 49 is also well adapted for this purpose.

TUBE APPARATUS.

776. *Tubes of thin glass*, of the size and form shown in fig. 96, are extremely convenient for numerous experiments where gases are evolved, liquids to be boiled, or solids to be heated and sublimed. Cases for holding them may be easily made of wood, of the form represented in figs. 97 and 98. Small retorts and receivers, pipettes and funnels, are frequently made with tubes, for operating on minute quantities of different substances.

CHAPTER XXXIII.

MISCELLANEOUS APPARATUS—MATERIALS FOR EXPERIMENTS.

777. Flasks of the form shown in figs. 100 and 101 are much used in a variety of experiments. Fig. 102 represents two small flasks, or bulbs of glass, connected by an intermediate

Fig. 100.

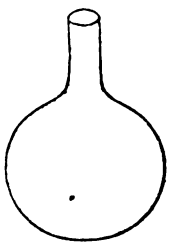
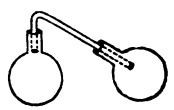


Fig. 101.

Fig. 102.

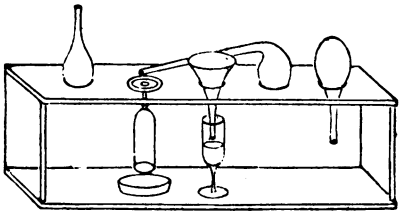


tube, so as to be used as a small retort and receiver. The wide

flask, fig. 100, if four or five inches in diameter, does well for burning phosphorus and other materials in oxygen; these are supported on a stand, as in fig. 35, the support being of a height equal to the length of the neck of the flask; the flask, full of oxygen gas, is then placed over the inflamed material; the mouth being downwards, and allowed to rest on rather a rough or grooved surface, that part of the oxygen may escape freely as the expansion proceeds.

778. Fig. 103 shows the form of a wooden stand with a

Fig. 103.



number of apertures, very convenient for giving a temporary support to retorts, flasks, funnels, and other apparatus.

779. Fig. 104 is intended to give an outline of a very plain form of a retort stand, which is extremely useful, and may be made in a very short time by any blacksmith. It consists of a small plate of wrought-iron, seven inches long, three broad, and one-half of an inch thick. A stem rises three-eighths of an inch in diameter, and ten inches long. Rings are made of iron-wire, which are supported by coiling the wire two times and a half round the stem. These may be moved readily upon

Fig. 104.

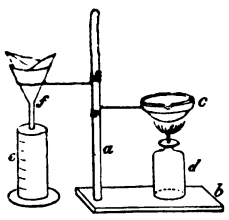


Fig. 105.

Fig. 106.

Fig. 107.

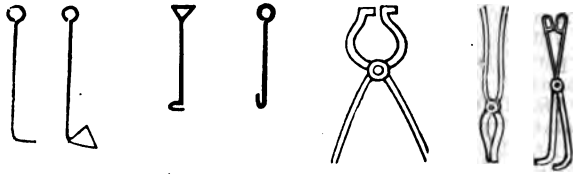
the stem, but when any weight rests upon the extremity, they become quite fixed.

780. Figs 105 and 106 show the form of the long funnel for

introducing liquids into a plain retort, and of a common funnel, such as is used for filtration. Fig. 107 represents a piece of filtering paper, folded in the manner required where liquids must be filtered quickly.

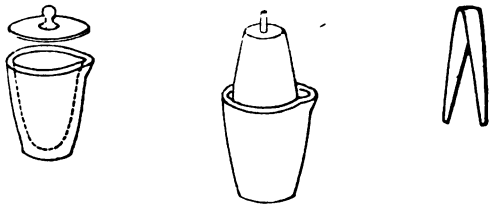
781. Figs. 108, 109—a rake and scraper required in furnace experiments. Figs. 110, 111, show the form of small wires of platinum, used for supporting minute quantities of materials in the flame of a lamp.

Fig. 108. Fig. 109. Fig. 110. Fig. 111. Fig. 112. Fig. 113. Fig. 114.



782. Figs. 112, 113, 114, represent different forms of tongs and pincers. Fig. 115—a crucible and its cover. Fig. 116—a crucible covered with another luted to it, gas being carried off at an aperture made in the top. Fig. 117—tin pincers

Fig. 115. Fig. 116. Fig. 117.



783. A conical piece of tinned iron, open above and below, being filled with clay, and a piece of hard wood of the same form, but a little smaller, being pressed into it, a crucible is at once obtained, which must be dried and heated slowly before it is used. The tin and the wood must be well oiled to enable the crucible to be removed. Small crucibles, two inches deep, one inch and a half wide at the top, and tapering a little to the bottom, are very convenient for numerous experiments.

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784. In using retorts, flasks, and crucibles, they should not in general be filled more than one-third full, where the materials are apt to effervesce or boil over.

785. Pneumatic jars (see par. 243, fig. 24) must be filled cautiously with water when they are mounted on the shelf *b*, to prevent them from being knocked over by any sudden movement in the fluid; the spout *c* leads any excess of water into the box *f*.

786. Small pieces of tin, copper, iron, and zinc wire, plate or foil, are very useful in experiments on the small scale.

787. *Solutions* are usually prepared by merely agitating the solid with water, or some other solvent, if it be very soluble; the mixture is boiled, if the substance be sparingly soluble.

788. *Equal weights* are always understood when the term "parts" is used, unless parts by measure be specifically mentioned.

789. Cubic inches are expressed by c. i., weight by W., volume by V.

790. The following table may be frequently referred to, so as to enable the experimenter to calculate the weight of materials used from the amount of the measure.

	Specific Gravity.	Weight in Grains of		
		1 Ounce.	1 Drachm.	1 Minim.
Distilled Water, - -	1·000	455·72	56·96	0·947
Sulphuric Ether, -	0·720	328·12	41·01	0·683
Alcohol, - - -	0·796	362·76	45·34	0·749
Solution of Ammonia,	0·925	421·54	52·69	0·878
Hydrochloric Acid, -	1·118	509·50	63·68	1·061
Nitric Acid, - -	1·480	674·47	84·30	1·405
Sulphuric Acid, - -	1·848	842·18	105·27	1·754

Memoranda.

60 drops or minims	=	1 drachm.	
8 drachms -	=	1 ounce.	
16 ounces - -	=	1 pint.	
8 pints - -	=	1 gallon.	
Imperial pint -	=	8750·	grains of distilled water.
Imperial fluid ounce	=	437·5	.....
Cubic inch - -	=	252·458	.....
Pound, avoirdupois	=	7000·	.....
Ounce, avoirdupois	=	437·5	.....

791. The small museums, with flat glass, prepared by Mr Macfarlane, consisting of about sixty specimens, with bottles containing the most important acids and alkalies, are extremely useful in enabling the student, who has neither time nor opportunity to operate with more extensive apparatus, to make himself familiar with a wide range of chemical phenomena.

792. The following list of materials and apparatus may be

useful to those proposing to commence a series of experiments by themselves.

[An asterisk (*) indicates that the substance before which it is placed should be kept in solution as well as in the solid form. Phials capable of holding from one drachm to two or three ounces, will do extremely well for this purpose. Boxes containing the materials, &c., represented below, should not cost more than about £3: when of the larger size, and intended for introductory courses in schools and academies, from £5 to £10 may be expended upon them.]

Sulphuric, Nitric, and Hydrochloric Acids; Solutions of Potassa and Ammonia—must all be kept in stoppled phials.

Sulphur.
Phosphorus.
Iodine.
*Fused Potassa.
*Carbonate of Potassa.
Bicarbonate of Potassa.
Sulphate of Potassa.
Nitrate of Potassa.
Chlorate of Potassa.
Bitartrate of Potassa.
*Ferroprussiate of Potassa.
*Bichromate of Potassa.
*Iodide of Potassium.
*Silicated Potassa.
*Carbonate of Soda.
Bicarbonate of Soda.
Phosphate of Soda.
*Oxalate of Ammonia.
*Carbonate of Ammonia.
*Hydrosulphuret of Ammonia.
*Chloride of Lime.
*Hydrochlorate of Lime.
Sulphate of Lime.
Phosphate of Lime.
Phosphuret of Calcium.
Fluoride of Calcium.
Sulphate of Baryta.
*Nitrate of Baryta.
Sulphuret of Barium.
Strontia.
*Hydrochlorate of Strontia.
Magnesia.
Sulphate of Magnesia.
*Alum.
Silica.

Iron.
Oxide of Iron.
Peroxide of Iron.
*Sulphate of Iron.
*Perhydrochlorate of Iron.
Lead.
Sulphuret of Lead.
Litharge.
Red Oxide of Lead.
Carbonate of Lead.
*Acetate of Lead.
*Nitrate of Lead.
Ore of Cobalt (Arsenuret).
Tin.
Bismuth.
Antimony.
Sulphuret of Antimony.
Copper.
*Sulphate of Copper.
*Nitrate of Copper.
Zinc.
Oxide of Zinc.
Arsenious Acid.
Sulphuret of Arsenic.
Binoxide of Manganese.
Mercury.
Binoxide of Mercury.
*Bichloride of Mercury.
Bisulphuret of Mercury.
Bicyanide of Mercury.
*Nitrate of Silver.
*Bichloride of Platinum.
*Terchloride of Gold.
*Tincture of Galls.

*Oxalic, Tartaric, and Benzoic Acids.
Cabbage, Turmeric, and Litmus Test-Papers; Filtering Paper.
Chalk or Marble, Sulphuret of Iron, and Borax, may be provided in larger quantity.

Pneumatic Trough with Shelf.
Pneumatic and Precipitate Jars, with Tin Trays.
Tube Retort, Receiver, and Funnel.
Basin for Evaporating.
Watch Glasses.
Test-Tubes.
Pipettes.
Bottle and Bent Tube.
Spirit-Lamp.
Glass Funnel.
Slips of Glass for Solution, Evaporation, Crystallisation, Fusion, and Testing.
Apparatus for Instantaneous Light.
Retort, Stand, and Ring.
Cupped Iron Block with Iron Bar.
Triangular Supports made of Wires of different Metals.
Crucibles.
Blowpipe.
Blowpipe-Lamp.
Blowpipe-Cups.
Brass Mould for making them.
Platinum Wire.
Supports for Candles, Sulphur, Phosphorus, Test-Tubes.
Iron-Wire, Slips of Copper and Tin.
Phials, Test-Tubes.

793. Paper dipped in different fluids is well adapted for illustrating a great variety of chemical phenomena. Dip different slips of paper into solutions of nitre, nitrate of lead, and nitrate of copper; dry them and set them on fire, so as to burn without flame; carbonate of potassa, highly alkaline, is produced with the first, metallic lead and copper with the others —the copper immediately attracting oxygen, and assuming a dull appearance.

APPENDIX.

CHAP. III.—In studying the chemical equivalents of elements and compounds, it should be recollected that there are numerous combinations where the state of the science does not admit that precise and specific statement as to composition which the progress of discovery may realise. This is more particularly noticed in many of the combinations of the animal and vegetable kingdom, though in the mineral kingdom also there are abundant examples of a similar nature. Albumen, fibrine, and caseine, for instance, are so nearly alike in composition, that they have been regarded as composed of one principle, termed *proteine*, and minute portions of other substances, so small in quantity, as not at one time to have been considered essential to their composition. Every succeeding day, however, proves the important action which even minute quantities of materials may have on chemical combinations, and therefore, if always present, they must be regarded as essential to the constitution of the compound into which they may enter, as those elements which are present in the largest proportion. One part of a peculiar substance found in malt, namely, *diastase*, will convert 2000 parts of starch into sugar, and still smaller proportions of special substances are known to exert the most powerful influence in numerous cases of chemical action. Slight changes of temperature, or the influence of water under circumstances where it might be apt to escape attention, equally demand attention; *starch*, which is insoluble in cold water, may be converted into a matter resembling gum, and termed *dextrine*, by the action of boiling water.

Fig. 118.

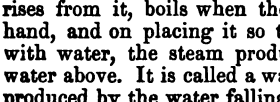
CHAP. VI.—The water hammer, the pulse glass, and the cryophorus, are three instruments in familiar use to illustrate vaporisation and evaporation at reduced pressures, and may be obtained at the philosophical instrument makers.

The *water hammer* consists of a glass tube, of the form shown in fig. 118, from which all air has been expelled by boiling the water within, and sealing it hermetically by melting the glass at the upper extremity as the steam escapes. The water within being thus protected

from the pressure of the air, and being subject to no pressure except that of the minute quantity of watery vapour that rises from it, boils when the instrument is held in a warm hand, and on placing it so that the large ball above is filled with water, the steam produced below is condensed by the water above. It is called a water hammer, from the loud noise produced by the water falling from one part to another when suddenly inverted.

The *pulse glass* (fig. 119) is prepared with alcohol in the same manner as the water hammer, all air being expelled by boiling the alcohol before it is sealed hermetically. When the ball *a*, placed so as to contain the alcohol, is held in the hand, it boils with rapidity, and is expelled by its own vapour to the ball *b*.

Fig. 119.



The *cryophorus*, or frost-bearer, like the preceding instruments, contains water, but no air. When a freezing mixture is placed around the empty ball *b*, as shown in fig. 120, a retort stand *c d*, retaining it in its place, the vapour in *b* is condensed rapidly, and fresh vapour rises so rapidly from the water in *a*, and removes so much heat from the water as it evaporates, that a thick crust of ice is soon formed on its surface. The name of the instrument is derived from Greek words signifying to bear frost. It illustrates beautifully many circumstances connected with evaporation which were previously demonstrated solely by experiments with the air-pump.

Fig. 120.

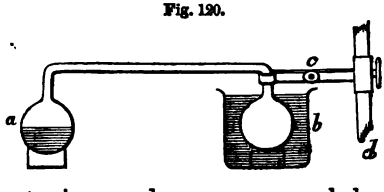
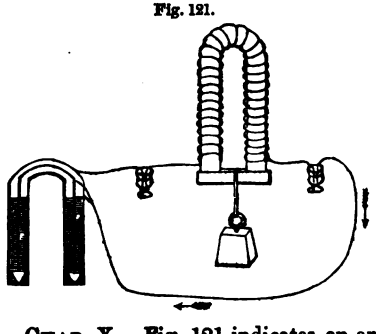


Fig. 121.

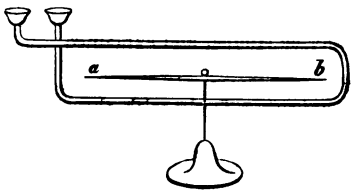


CHAP. X.—Fig. 121 indicates an apparatus in general use *for illustrating* the development of magnetism in a piece of

soft iron by electricity. It consists of a copper vessel made of a double copper cylinder, into which nitric acid is poured, diluted with different portions of water according to the effect required. A cylinder of zinc being introduced between the copper cylinders, a galvanic action is commenced. Wires attached to the copper and zinc are led into small cups containing mercury, to facilitate adjustments. A bar of soft iron bent in the form represented is then subjected to the galvanic influence by placing the extremities of the wire coiled around it in the mercury in the two cups mentioned. On approaching a piece of iron, which may be loaded with a weight to the extremities of the iron bar round which the electricity passes through the copper wire, it is instantly attracted and retained, but falls at once when the electric circuit is broken, by taking any of the wires out of one of the cups containing the mercury.

Fig. 122 indicates a magnetic needle *a b*, and a brass wire arranged so as to show the principle on which electric telegraphs are constructed. When mercury is placed in the cups attached to its extremities, on introducing into the mercury wires from a galvanic battery, the needle is instantly deflected, and thus gives an indication which may be varied according to the wires connected with each extremity, or repeated any number of times, so as to afford thereby different signals.

Fig. 122.



In exploding gunpowder in mines below water, or in other places by galvanism, the match that kindles the mixture is an inflammable composition placed between the extremities of wires connected with a battery, and sometimes it is merely a platinum or iron wire, which becomes white-hot as the electricity is made to traverse it.

In electrotype operations, the metal deposited is separated in the same manner as crystals of metallic bodies are separated from their solutions, the mould to which the metal adheres being suspended in, or covered with, the solution depositing it.

CHAP. XI.—When a small quantity of oxygen is required from chlorate of potassa, which is now prepared at a much less price than formerly, and therefore more available for experimental purposes, it may be obtained with comparative

facility when procured by heat from this salt fused in a green glass retort, if a little powdered peroxide of manganese be mingled with it. Green glass retorts are mentioned, as the proper variety of green glass for such retorts contains no oxide of lead, and is much less easily softened or fused on the application of heat.

CHAP. XIV.—In no department have the application of chemistry been more important in recent years than in respect to the comfort and economy of the arrangements made for the ventilation and heating of houses, as well as schools and public buildings. Till proper measures are introduced as part of the original designs for buildings, instead of being appended to a structure built without reference to them, these matters can never attain the proper position in which they should be placed, either in respect to efficiency or economy. In the meantime, however, as architecture in these and some other respects must be considered in a state of transition at present, too much publicity cannot be given to the principal resources that are available for improving health. In addition to the illustrations given under *Ventilation*, the following may be studied and explained.

In individual apartments, particularly in bedrooms, when fires are not used, and windows are shut, the fireplace communicating freely with the open air by the chimney, the air below the level of the head of any person asleep at the usual level may be comparatively pure, while that breathed, and in general that above the head, may be offensive, and productive of an unrefreshing and anxious sleep. A fire, if not sustained all night, may prove oppressive, or even dangerous in some cases, if there be a back draught when it is declining. And if the night be cold, and the air entering pass at a low level (the case indicated in fig. 123), a current may be sustained in the direction shown, the rest of the air being comparatively stagnant. The great remedy in all such cases is to provide a superior aperture, of which examples are given in the subsequent figures.

Fig. 123.

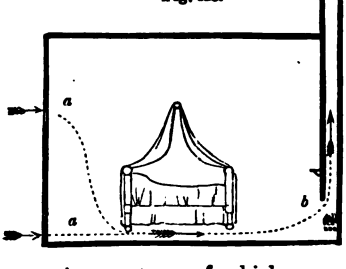


Fig. 124 shows an example of back draughts, such as are

often observed in apartments where there is a defective supply of air, the large fire below obtaining its supply by drawing air down through the chimneys of the weaker fireplaces above, which are overpowered by its action. In some cases even a portion of its own smoke may be returned in this manner. The great fault requiring correction in this case, is the want of any adequate supply of air in a house too carefully finished to admit, by leakage at doors or windows, a sufficient amount of air. In many instances, were chimney flues reduced in size, so as to discharge less air, and a freer admission of air permitted into passages or staircases, back draughts would be entirely prevented. It is the want of adjustment between the supply and demand of air by the fuel kindled, and the chimney in connection with it, that is too often the permanent cause of smoke. Nothing is so economical in respect to health and comfort as the provision of abundance of warm air in the passages of houses, as this maintains a comparatively equal temperature throughout the whole house. No cause is so frequently productive of colds, catarrhs, and inflammation, as the influence of rooms at very different temperatures in the same house.

Fig. 124.

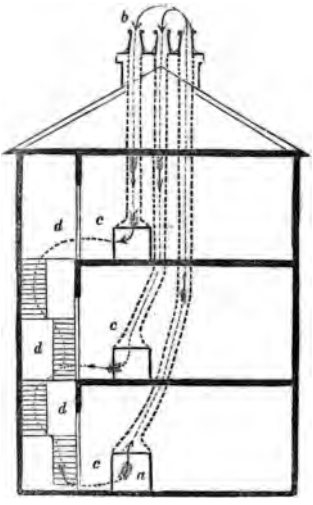


Fig. 125.

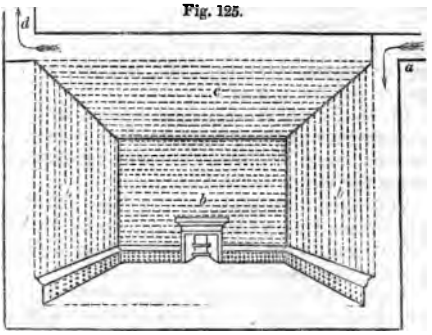


Fig. 125 indicates an apartment constructed for an invalid, who was exceedingly sensitive as to currents, and required that the air should reach him with the least sensible impetus. The arrows indicate the progress of the entering air by the most extreme diffusion, and the escape of vitiated air by the ceiling.

In the woodcut 126, eight figures are given, which may be studied with the view of showing the comparative advantage and disadvantage of different movements of air.

I. indicates the entrance of air through a door provided with porous pannels from a warm passage, no escape taking place except by the chimney *b* of the fireplace *x*.

II. indicates a room supplied with air by a porous pannel above the door, the circumstances being in other respects the same as in No. I.

III. This figure shows a room in which a superior aperture is secured for the discharge of vitiated air. Sometimes this aperture is made into the chimney, where there is no risk of accident by fire, and a valve introduced, such as has been recommended by Dr Arnott, to prevent return draughts.

IV. In other cases, rooms have been constructed so as to admit air by the cornice, and allow the vitiated air to be discharged by a separate aperture above. The tube *o* shows a ventilating tube from a gas lamp, by which the products of combustion are carried off, all the arrangements being made fireproof so far as may be necessary. Nothing contributes more to the comfort of apartments lighted by gas, than the direct removal of the products of combustion.

V. indicates an apartment with a porous ceiling and a porous floor, capable of being ventilated to any extent by an ascending or descending movement, according to the nature of the power applied at *a* or *b*.

VI. shows the movement in a room where external apertures admitted air at every portion of the cornice, the force of the current being broken afterwards by porous canvas extending along the whole surface of the wall.

VII. This figure shows the less diffusive movement that takes place where there are no porous wall.

VIII. points out the movement that ensues where the ceiling is made porous instead of the walls.

Each of the preceding movements has special advantages and disadvantages. No arrangement will suit every kind of weather and every variety of crowding, that does not give power of adjustment according as the circumstances are varied. Fig. V. admits of more variety of adjustment than the others, but no one must expect to satisfy all constitutions

equally in the same apartment, so long as men have differences of temperament and habits.

Fig. 136.

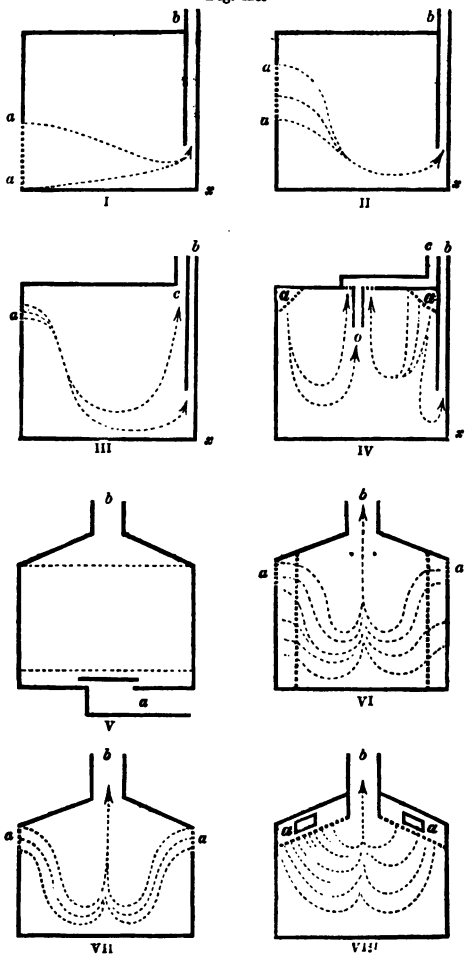
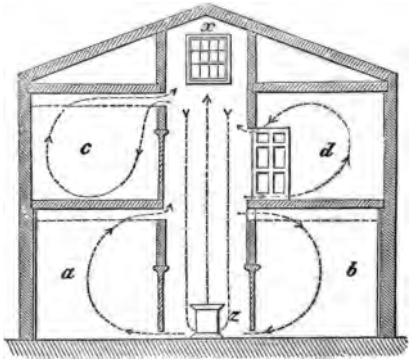


Fig. 127 indicates a staircase receiving a general supply of air by the window *x*, to which any degree of warmth may be communicated by a heating apparatus at *z*. This will obviously maintain a circulation such as is indicated there. The amount of egress, as well as ingress, is regulated by the openings at *x*; stairs are omitted, that the circulation of the currents may be more easily traced. It will be obvious that

Fig 127.



movements will be induced between the contiguous rooms and this central reservoir whenever communications are made between them, producing varied currents according to the temperature and structure of each individual apartment. In the figure, the operation of chimney flues and windows is entirely excluded.

a indicates colder air from the passage, entering below the door, and forcing out warmer air by a porous ceiling through a valve above the door communicating with the staircase.

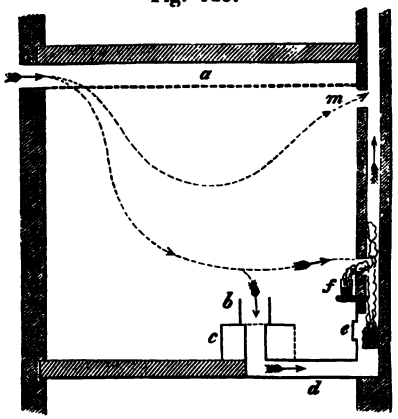
b indicates a movement under different circumstances, warm air from the passage descending through this apartment while colder air escapes below.

c indicates a room with air-tight doors, but ventilated by a descent from the ceiling and a discharge by the upper portion of the same aperture by which the air enters from the general reservoir.

d indicates a movement of air precisely similar to that indicated in *a*, except in so far as the movement takes place through the lower and upper portion of an open door, instead *of through* crevices in the door and through a perforated *ceiling.*

Fig. 128. When a number of chemical experiments are performed in any ordinary apartment where proper facilities for carrying off offensive fumes have not been made, arrangements such as are indicated in this figure may be easily introduced, carrying them to a greater or less extent according to the quantity of materials with which it may be desired to operate.

Fig. 128.



a indicates any opening for the admission of air which may be introduced by a window, or, when circumstances permit, through a gauze stretched so as to form a chamber for diffusion between it and the ceiling. By dipping it in a solution of muriate of ammonia before it is suspended, should an incombustible material not be employed, it is rendered difficult of ignition.

b indicates a glass cylinder open at the top and bottom, and resting on a grating in the table *c*, through which any fumes may be carried downwards from materials placed within it.

d, a tube about nine inches in diameter communicating with the fireplace. The tube may be made of iron, earthenware, or bricks.

e, an iron plate closing entirely the open fireplace, so that the fire is supplied only through the tube *d*.

f and *m*, apertures at different places communicating with the chimney, which may be opened for the discharge of fumes and vapours when *b* is closed by a cover laid upon the top.

Instead of an iron plate at *e*, the front of the fire may be bricked up, an aperture being left as is indicated in the iron plate for the management of the fire and the supply of fuel.

Figs. 129 and 130. These figures show a mode of arra an open fireplace in ordinary rooms, and of supplying them warm air, which has been found very advantageous in places where the supply of air was objected to when pro in any other manner.

Fig. 129.

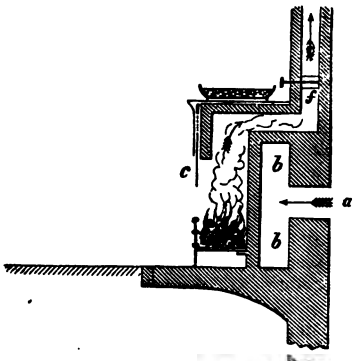
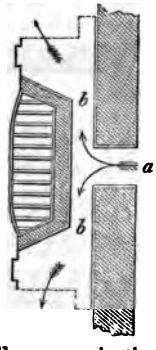


Fig. 130.



a indicates an aperture in a wall communicating with external air.

b b, a chamber between the fireplace and the wall, in which air is heated before it enters laterally through a porous struc

The fireplace is made much in the same manner as stoves, but lined with fire-brick in the interior. A blowe can be made to descend to any extent, so as to accelerat combustion. A basin of water on the top supplies moi when necessary to the warm air; a valve at *f* regulate *draft.*

If the teacher in primary schools bears in mind, th

presenting youth with the elements of chemistry, he enables his pupils to become acquainted with the leading features of a science that forms the true key to the interpretation of innumerable phenomena of nature and of art that are objects of daily attention, he will then see that his initiatory lessons, multiplied by his pupils' experience in daily life, will be equivalent to a much more extended course, in proportion as his instructions teach them to identify the lessons received with external objects and the structure of their own frame. At the same time, the spirit of inquiry which he will stimulate in his own district will necessarily awaken individuals distinguished by their powers of observation to enter and improve different branches of science, while it will render more available to all the powers and resources which the Author of Nature has provided for man in the material world. He must, accordingly, regard his instructions in this department as contributing essentially to advance objects of the highest practical importance to society. In particular, he should remember—

1*st*, That systematic instruction in science can be advantageously introduced in elementary schools.

2*d*, That this is a question of national importance, affecting equally the resources of the affluent and the necessities of the poor.

3*d*, That such instruction will contribute to the improvement of agriculture, and the development of new sources of industrial employment.

4*th*, That it is essential to the proper education of agriculturists, medical men, architects, engineers, manufacturers, and emigrants.

5*th*, That it is necessary to meet the wants of an increasing population.

6*th*, That it will unfold never-ceasing opportunities of interesting observation as well as of profitable employment, bearing on the fine arts, the useful arts, and the general progress of sanitary improvement.

These positions have been illustrated in numerous lectures and demonstrations, and also in evidence given before a committee of the House of Commons in 1835. In 1842, under the sanction of the Committee of the Privy Council on Education, they were illustrated in detail to one thousand teachers in London and its vicinity, in a series of twenty lectures given at Exeter Hall, five hundred young persons attending at the same time from different public and private schools.

At that period the formation of a society in London for the improvement of health, the institution of a scientific association for teachers, and the examination of different districts

in London by members of this association and other parties continued to engage attention till the Health of Towns Commission was instituted by her Majesty's government. The association mentioned held its meetings in a model-room constructed at 15, Duke Street, Westminster, as a temporary class-room, and in reference to sanitary improvements. It has latterly been occupied as a laboratory attached to the Museum of Economic Geology.

The progress made in the more general introduction of chemistry since that period, is attested by the numerous establishments in which this science is now taught, where no instruction had been previously given in this department; and while many concurring causes have contributed to accelerate this result, it is impossible that any one can look back to the state of this question for fifteen or twenty years, without some satisfaction at the totally different aspect which it now presents. And though it can only be considered as beginning to engage attention in the more extended form required to meet the wants of society, the preceptor in the elementary school has now the most ample means of satisfying himself, that without his assistance in the introduction of science, the pupil at universities, and the apprentice to the agriculturist, the medical man, the architect, the engineer, and the manufacturer will be as deficient in the basis of his professional education, as an Oxford or Cambridge student would be in classics or mathematics were he never to acquire any instruction in Latin or arithmetic till he should join college in either university.

"4856.—I would have no hesitation in saying, that were a course provided not merely for artisans and mechanics, but for the common people, in which those subjects alone should be introduced that bear practically upon their own comfort and convenience, it might have the effect of doubling the value of the poor man's income to him."

"4860.—I look upon the knowledge which is communicated in the study of physical science, of the economy of the human frame, and its relation to external agents, as so important in reference to health and comfort, that on this ground alone, were no other brought forward, I would advocate the study of physical science."—*Extracts from statements made by Dr. Reid in* 1835.—*See Report on Select Committee on Education, and Evidence (Ireland); Thomas Wyse, Esq., M.P., chairman.*

It is trusted that these notes will assist the teacher who may not previously have attended to this subject, in tracing the extreme importance of the systematic introduction of the *elements of science* in primary schools. It will be well, however, *for all who* desire to become more familiar with the extreme

importance of the relations of those chemical agencies that affect man more or less in every condition of life, to conclude the study of the preceding pages with the careful perusal of the following Summary, and to consider, as practically as circumstances may permit, his own position in reference to the varied points to which they refer.

BRIEF SUMMARY OF THE PRINCIPAL CHEMICAL AGENCIES AFFECTING THE DURATION OF HUMAN LIFE.

In a chemical point of view, the materials of which the body is composed are subjected to a continued series of changes throughout the whole period of life. They may be influenced by the vital powers to a degree and in a mode that has not hitherto been developed or explained; be this as it may, the chemical agencies of the different elements do not appear to be changed, the wonderful organisation or apparatus in which they are placed being the cause of all those peculiar results that arise whenever they are received within the circle of living action. (638, p. 129).

To take an example from a familiar case of chemical action we may refer to the combustion of fuel under different circumstances, and compare these with the varying conditions under which chemical changes may ensue in the living frame. The fuel may be consumed in the open air, or the combustion may be extinguished from the exclusion of air. In a fireplace the combustion is more perfect and more easily regulated. In a furnace, the intensity of heat is greater, but the duration of the combustion is proportionally diminished. With a blast from a bellows, a still more powerful but more brief effect is developed. Let the fuel be charred and mixed with nitre, which may be regarded as a condensed atmosphere of air or oxygen, and the whole may be consumed with explosion in an instant, as during the detonation of gunpowder. Lastly, all such changes must be more or less influenced by the very quality of the materials used, whether we look to the fuel employed or the different conditions of the air or other matters brought to act upon it.

So, in the same manner, with the materials of which the body is composed, making allowance for the great difference of circumstances, they may be consumed slowly and equally, and life sustained for a long period by the temperate and equal supply of food, the right selection of materials, and the proper control of the mind in whatever way it may affect the body. Or, by excessive exercise, the use of stimulants, exciting

passions, and over-exertion, whatever the cause may be, these chemical changes in the living system may proceed unequally, with undue rapidity, or terminate in a moment, as on the administration of a fatal dose of any poison that instantly induces changes incompatible with life. The animal frame may also, like different varieties of fuel, be very various in its composition, and prone to death in one instant from very slight causes. Or, it may be tenacious of life, and resist for a long period agencies that would overcome, almost without a struggle, a feebler condition of bodily existence.

Excluding accordingly in these remarks, the consideration of all those questions that come more especially within the province of physiology or other departments of science, the following points require attention, particularly as affecting the quality, the quantity, and the mode in which any material is brought to act chemically on the Human Frame.

Let it be also recollected that in one case the blood may predominate, in another the nervous system, in another the muscular system, and so on indefinitely, and in endless varieties of combination, throughout the whole materials or textures of which the body consists, each having peculiarities that may render it more amenable to some influence, or protect it from others, according to the circumstances of every individual constitution.

The statistics of different places indicating an extreme variety in the duration of human life, and the progress of practical science having pointed out many preventible sources of disease and death, it is fair and reasonable to assume that the present average length of human life in different districts cannot be held as any certain indication of what the value of life may become, in proportion as the knowledge of former and recent years may be practically applied in improving the condition of mankind. In some places, half the population have been known to die under five years of age. In others, numerous well attested cases of longevity occur, notwithstanding extreme exertion, great privations, and other known and admitted causes unfavourable to the prolongation of life. When, therefore, the advantage of a good constitution shall be combined with all those appliances that are calculated to give pure air, proper exercise, well selected food, and those habits of mind and body that are favourable to length of life, it is not too much to expect that a very material addition may be made to its duration. It has been frequently stated that this question *has been already* settled, and that the days of man are, on the *authority of the* 90th Psalm, but threescore and ten. This, *however, is considered* by eminent commentators to be a very

erroneous interpretation of the 90th Psalm, which is translated as expressive of regret that at a particular time the duration of life had been reduced to that period, and not as an authoritative announcement that seventy years was to be the term of human existence.

FOOD.

In the supply of food, the first fact requiring attention is that it shall contain all the elements requisite for the structure of the human frame. One article of diet is not in general sufficient for the maintenance of life, however large the quantity, unless of a complex quality, such as the most nutritious grains. Sugar, for example, containing no nitrogen would be totally unfit in itself either for the production of blood or muscular fibre; wheaten flour contains much gluten, in which there is abundance of nitrogen, and is therefore highly prized as an article of food. The potato, on the other hand, being deficient in this respect, is proportionally less valuable.

Exclusive of the presence of carbon, oxygen, hydrogen and nitrogen, which constitute the great mass of the materials required for food, and are therefore termed the primary organic elements, many saline and earthy substances are required in small proportion which are essentially necessary for the maintenance of life, and the production of various tissues that are formed in the living frame. Potassa, soda, lime, iron, sulphuric, phosphoric and muriatic acids have been found in the bone, in the blood, in the muscle and other animal products. Other combinations of sulphur and phosphorus have also been ascertained to exist. Even silica and fluorine have been noticed, the latter in combination with calcium in the enamel of the teeth. The blood in the human frame is always alkaline, and free muriatic acid may be separated by distillation from the contents of the stomach in certain stages of digestion. The great point to bear in mind, however, is that where a proper proportion of animal and vegetable food is available, there the body can receive the highest development with the least tear and wear of the energies of life; and that in nations, as in individuals, a defective quality of food in point of chemical composition is always attended with pernicious results.

Next to the composition of food, the most important point is the condition in which it is administered. Though the art of cookery has existed from the remotest period, every day's experience shows the extent to which it may be improved even *in the most ordinary* operations; for example, in preparing *meat for ordinary* use by heating it in water, the best plan is

to place it at first in boiling water, maintaining it in this condition for a few minutes only, so as to form an impenetrable crust or shell on the outside of the mass, after which the operation is most advantageously completed at a temperature of about 160° F. If a contrary process be adopted, commencing the action with cold water and with the meat cut in slices, the temperature being very gradually raised, excellent soup may be formed, but the meat itself is comparatively insipid, being deprived of the juice and saline matters that are retained by the previous process. If boiled from first to last, the heat being maintained constantly at 212°, the internal portions acquire the same toughness as the external crust.

It is scarcely necessary to remark that a much more systematic attention to the chemical details of cookery than has in general been accorded to it, will prove equally a measure of economy, and promote the production of a more palatable and nutritious food.

In respect to the quantity of food required for sustaining the human frame, as a deficiency retards development, so an excess proves injurious in a twofold mode, not only overloading the system to an extent which the existing apparatus cannot overcome, but leaving materials subject to spontaneous chemical changes within the frame, if not controlled sufficiently by the action of the gastric juice, the bile, and other matters, to whose full operation it should be subjected during the ordinary process of digestion.

Again, in looking to the various materials that are used along with the more plain and substantial articles of food, a very little reflection will show that these must each individually exert peculiar effects according to their special composition and properties, augmenting or diminishing the energy of particular organs, or acting on all through the blood, to which they may impart peculiar properties. Tea, coffee and tobacco, each produce specific effects. Beer, wine, and other spirituous liquors, all convey alcohol to the blood, the evaporation of which in the air-cells of the lungs, or as it is discharged by the pores of the skin, may be attended by a consumption of oxygen, producing for a time increased temperature and an unusual development of carbonic acid. These are productive of injurious effects, independent of the direct effects of the alcohol before it is discharged, and the consumption of part of that oxygen that would otherwise have been available for the whole system, whenever they are consumed *too largely, nor* do they appear, except when required *medicinally, to be in* any way requisite for the preservation of *health.*

Lastly, articles of food are unfortunately as much subject to adulteration as any other matters that are the objects of commercial speculation. Many details, however, connected with their preparation, often lead to their accidental contamination where there may be no fraudulent intention, or where some special ingredient may be added to produce a particular effect. Thus alum and other substances added in certain proportions to wheaten flour may improve the appearance of the bread made with it, but many constitutions suffer severely from the constipating effects which it produces without suspecting the cause. On having recourse to a different kind of flour, less fine in quality, and free from such additions, health is again restored.

AIR.

The paragraphs on air and its elements and on ventilation having explained the more important chemical facts connected with its history, it is desired in this note to point out emphatically the extreme magnitude and continuity of its operations in its action on the human frame.

If it be remembered that it is ever in contact with the surface of the body, and that the provision made by nature for applying it directly to the living blood in the human frame produces no less than twenty-eight thousand eight hundred respirations every twenty-four hours, we shall then form a better opinion as to its incessant action, and of the important results that must follow its operation. It is also to be recollected that the surface of the air-cells in which the blood is distributed throughout the lungs exceeds by many times the whole surface of the body, and thus affords the most ample opportunity for their intimate contact. Nor is this all; the oxygen is considered to be absorbed by the substance of the blood and carried thereby to every fibre of the living system. But all such arrangements are impaired in their action whenever respiration is carried on in a room or locality where the atmospheric air is not sufficiently pure.

The atmosphere being the great emporium into which all gases and vapours ultimately pass, there is nothing that can evaporate or assume the gaseous form which it may not contain. All animal and vegetable matters tend ultimately to develop carbonic acid and water, and therefore, in searching for local causes of impurity, we may omit their presence, unless the proportion be steadily and permanently augmented *from the operation* of some local cause.

Where clay predominates, the soil being comparatively im-

pervious to moisture, it tends to remain on the surface of the ground until evaporated by the action of the sun and air. In such districts accordingly, the air is generally more or less loaded with moisture.

Where gravel abounds, the water escaping with facility from the surface leaves the superincumbent atmosphere comparatively dry.

Low lying situations are subject to an excess of moisture from the water that generally accumulates there, and also to the predominance of fog, mist and dew whenever the temperature of the air is not sufficient to retain the evaporated water in solution.

Where large tracts of land are loaded with water, and vegetation at the same time prevails, emanations arise whose precise nature is imperfectly understood, but which are prone to induce fever by their action on the human frame. The more rich and luxuriant the vegetation and the greater the debris of animal and vegetable matter associated with it, the more prone is the district under particular conditions of the atmosphere, and at certain temperatures, to discharge offensive products destructive to animal life. At a low temperature and at a high temperature these changes take place in a less degree, or become altogether arrested.

When such emanations are conveyed through the air to the body, they are absorbed by the blood in the lungs, and many fevers appear to be developed in this manner, the successive changes that ensue during their progress being intimately connected with, if not absolutely dependent on, chemical changes induced in the blood by the matter communicated to it.

In high and elevated situations, not only is the air comparatively free from impurities, but its relation to moisture is so altered, that evaporation proceeds much more rapidly than at a lower level, and many who are subject to a depression and loss of strength at a lower level acquire a gaiety and elasticity of spirits in a higher level, which is largely connected with this cause. Others, again, give a preference to a lower level.

In countries that are highly cultivated great changes are often induced in the state of the air, the growing vegetables consuming as their natural food many substances that would otherwise run into offensive putrefaction and decay. The drainage of the land also, wherever it is introduced in the effective manner recommended by modern agriculturists, largely improves the condition of the atmosphere.

The peculiarities of each individual constitution render it amenable to various effects from one and the same atmosphere, according to its relations to heat and cold, the freedom with

which moisture passes through the skin, the irritability of the lungs and the nature of the diet, occupation and exercise.

The emanations from manufactories are often exceedingly deleterious, and may exist of any products discharged in the form of gas or vapour, and loaded with charcoal or other matters mechanically suspended in them.

All such emanations may be destroyed by fire, condensed by water, or retained by mechanical arrangements adapted to the processes in which they may be disengaged.

The term smoke is applied in common language to a great number of products, continually varying according to the materials from which they arise: among these the following should be particularly noted in addition to those mentioned in 416, p. 94.

1. THE DENSE BLACK SMOKE of manufactories consists essentially of carbon in a minute state of division, and indicates imperfect combustion and great irregularity in the supply of fuel, or a very objectionable method of introducing it into the furnace, except in those cases where the operations in progress require an atmosphere loaded with smoke. In a great majority of cases the amount of smoke discharged may be greatly reduced with advantage to the manufacturer.

2. SMOKE from CHARCOAL, coke and anthracite is generally invisible.

3. SMOKE from WOOD is rarely black, but when wood is heated in manufacturing operations for the preparation of acetic acid, a very irritating tarry vapour is discharged.

4. SMOKE from SULPHUROUS COMBINATIONS. In many manufacturing operations sulphur is evolved in the form of sulphurous acid, SULPHURIC ACID and SULPHURETED HYDROGEN. Few ingredients from chemical manufactories have been more largely produced or been more injurious to human life in densely populated districts. Remarkable instances have occurred where the workmen in the manufactory have been subject to no complaint, while those in the vicinity have suffered severely. The reason was that the flues withdrew all the offensive compounds from the men, discharging them outside through the chimneys to the injury of their neighbours.

5 SMOKE with HYDROCHLORIC ACID has perhaps been discharged in larger quantity than other acid vapour. It has been produced principally in alkali works during the preparation of soda.

All these acid smokes are not only injurious to animal life, but also very inimical to vegetation. Many of the tall chimneys, sometimes exceeding three or four hundred feet in height,

that are observed in manufacturing districts, have been constructed with the view of conveying such fumes to a distance, the dilution attendant on their motion through the air rendering their effects less marked when they fall upon the ground at a distance. So great is their intensity however, that they may be tasted distinctly on some occasions at a distance of miles from the manufactory in which they are produced.

6. METALLIC SMOKE. The fumes from lead and other metals, more particularly arsenic, are of a very deleterious nature, and are sometimes carried for miles in horizontal flues before they are permitted to escape into the external atmosphere. They consist principally of the oxidated metals in a minute state of division.

7. EMPYREUMATIC SMOKE from organic products subjected to heat, however offensive, may be decomposed by causing it to pass through a red-hot furnace.

8. PUTRESCENT SMOKE or VAPOURS may be treated in the same manner as that in the preceding case. The amount of injury to health which they produce can scarcely be credited except by those who have minutely investigated this subject.

Lastly, all accumulations of decomposing organic matter, whether collected for manufacturing operations or other purposes, must be regarded as a source of offensive emanations injurious to health. Among these none is perhaps so pernicious in large towns and populous districts as the interment of the dead in the midst of the living. Till legislative enactments shall have effectually put a stop to this practice in towns, they will never be free from one of the most oppressive sources of disease and death.

WATER.

Water being an agent of such universal importance, and in daily use for so many varied purposes, too much attention cannot be bestowed in securing an abundant supply from a pure and wholesome source. It is to be remembered also, that it penetrates the whole system and forms the largest portion of the blood itself, constituting nearly four-fifths of its weight. It is therefore the medium through which all nourishment is conveyed to every portion of the system, all decaying particles removed during the ever-changing conditions of life, and noxious products cast off which would prove the source of disease, were they not continually removed by its operation.

In studying the properties of water in relation to health, and bearing in mind, in addition to the facts explained in *Chapter XI.*, that the purer the water and the more free from

colour, taste and smell, the more generally available will it be for all ordinary purposes, it is important to examine the cistern or reservoir in which it may be kept for daily use, and the sources of contamination to which it may be there exposed.

All wooden cisterns are prone to decay, and reservoirs of stone or metal are therefore much preferred, where no special chemical properties of the water forbids their use. Even there, however, periodical cleansing should be systematically resorted to as the only certain means of retaining them in a proper condition.

Again, all water cisterns are usually provided with a waste pipe which is sometimes conveyed directly to an adjoining drain. When this is the case, unless a bend in the pipe, or some other equivalent arrangement shall cut off all direct communication between the drain and the cistern, it may become largely contaminated with impregnations from the drain, the tube conveying emanations from it to the surface of the water where they are absorbed. In this manner not only the water but the atmosphere of the house generally in which such tubes exist may be contaminated with an indefinite amount of gaseous products arising from an equally indefinite area of drains, according to their distribution in the vicinity and connection with other drains.

If the water in use be supplied by a public company, information as to the source from which it is obtained and the operations to which it may be subjected should be procured, if either chemical tests or any other cause lead to a suspicion of its wholesomeness.

In some districts the presence of earthy salts, particularly when combined with certain varieties of food or drink, are considered to promote the formation of calculus complaints, one of the most severe maladies to which humanity is subject.

All water exposed to any admixture from drains can never be considered equal to that obtained from unobjectionable sources, though a good system of filtration and aeration of the water by exposure to air and percolation through porous materials may reduce largely any source of offence.

By fermentation, by charcoal and by the action of lime (subsequently separated as a carbonate on exposure to the air), water loaded with impurities may often be rendered fit for use. But such processes are only to be resorted to as a matter of necessity, in extreme cases, where a proper supply of good water cannot be obtained.

Where water is obtained from a common pump or well, too many inquiries cannot be made as to the sources from which

it derives its supply. It has too often happened in populous districts that such wells are contaminated by the infiltration of impurities from graveyards, drains, cesspools, gas-works and other manufactories. Nothing but a local inspection can give any real security as to the source and quality of the water.

In artesian wells the water springs up from a variable depth, whenever a superincumbent and impervious bed of clay or other material shall have been penetrated. From such sources water free from organic matter may be obtained, but it is often highly charged with salts of soda and lime.

All water that deposits a thick crust in the tubes in which it may be conveyed, or when used in a boiler, should be carefully examined so as to note the precise amount of impurities it may contain. In some cases, by boiling and subsequent filtration, or the deposition of a sediment, such waters become extremely pure.

The great purifying influence of water upon blood arises from its power of solution, and the extent to which impurities adhere to it. Accordingly as large quantities may be added to it, and discharged again with rapidity, few agents contribute more to the preservation of health, if, at the same time, other liquids charged with noxious impurities or intoxicating spirit be avoided. It may be said in such cases literally to wash the blood, and consequently to purify and refreshen the whole system. Fever and some other diseases are sometimes arrested by its action in a short space of time. The most effectual mode of applying it where it is required to act on the blood or the skin consists in combining its action with that of steam and warm air. The skin should previously be well washed with hot water, to which a very little caustic potash is added that the pores of the external surface may be freed from all external covering. The patient then sitting on a chair placed in the bath box, and subjected to a current of warm air mixed with steam, perspires freely, the heat and moisture accelerating the circulation and relaxing the skin. A warm shower-bath placed above him washes the surface from time to time and removes all sensible perspiration. By giving warm, palatable diluents, the action may be maintained with energy as long as may be requisite. In this manner individuals labouring under an offensive breath, having the heavy and oppressive character of that observed in fever, have it restored to its natural character often in a quarter or half an hour, and escape the attack which may have otherwise been impending over them.

It is curious to remark that cold water, hot water and *numerous other* remedies have been used in fever from time *immemorial*, with the view of cutting them short by inducing

perspiration; but by the combined action of heat, air, water and steam in the manner described, their chemical agencies are more effectually developed with rapidity and without injury to the patient than in any other way.

CLOTHING.

Porous clothing, made of flannel, or that which most nearly approximates to it, conduces most highly to health, permitting freely the ingress and egress of air and gases, while it is not liable to cause that feeling of cold or that sudden checking of perspiration which is apt to be produced by linen or other materials of a different texture.

All waterproof and airproof clothing, however useful in temporary circumstances, obstructing the natural perspiration altogether, or returning it in condensed moisture on the skin, and excluding a proper supply of air, ought to be avoided as much as possible. Even a light waterproof cloak placed loosely round the person obstructs the perspiration to such an extent as to be injurious to many constitutions.

Fortunately the practices and opinions of the present day are generally hostile to that deformity and destruction of health that necessarily arises from an undue compression of the chest, though there are still too many individuals who are not sufficiently aware of the injuries they inflict upon themselves in this respect. Could they see for a moment the distortions they produce, or the manner in which the whole machinery of circulation and respiration are affected, they would perhaps be induced to take a lesson in time before the general health gives way. Everything that tends to diminish the cavity of the chest necessarily renders the lungs less fit for keeping the amount of blood the body requires in good condition, independent of the injuries that may be caused to particular organs. The chemical changes ever in action throughout the living frame are consequently performed with less energy and with an imperfect material.

In young and old persons, in particular, it is important that the temperature of the feet and hands should be carefully attended to as the circulation is apt to be carried on languidly there in proportion to their distance from the heart.

At a period when the whole subject of clothing is engaging a more marked attention than it has ever attracted in previous days, the deep close confined boot should be abolished for *a more open texture*, wherever special exposure does not necessitate its use.

HABITATIONS.

In selecting a house for a permanent dwelling, the following are the more important chemical points that demand attention, many of which will suggest themselves in each individual case that are purely of a local character.

1. THE FOUNDATIONS. When the foundations of a house do not rest on a hard, dry, rocky or gravel bed, or where moisture from any cause is apt to come in contact with them, it is of primary importance to take every available opportunity for the exclusion of damp. Whenever the drainage or other circumstances do not secure this, the occupation of the lower apartments at least will be detrimental to health. The water from damp foundations extends to a variable height in porous stone, brick or plaster work. A layer of cement or slate is often used to prevent its progress beyond a particular point. Metals have been employed for the same purpose. A layer of asphalte or pitch is perhaps still more effectual, more economical and less liable to decay. In some cases a course of bricks has been built above this layer, the bricks being thoroughly dried and heated first, and laid with well-boiled soft pitch instead of mortar.

2. MATERIALS. The less pervious the materials to moisture and the less their conducting power for heat, the more comfortable in general will the house be. An inner coating of lath and plaster, or of paper extended upon canvas, tends still more to keep out external heat and cold. The numerous resources afforded by iron, glass, cements, bricks and tiles have introduced fire-proof materials to a great extent in many buildings, rendering protection from external heat and cold often more necessary than in former structures, the thinness of the walls, as well as the material employed, contributing to this result.

One great advantage however has ensued, namely, the diminution in the danger from fire; and it would be well were fire-proof materials to be used still more largely in the construction of the fittings, and even of the furniture of ordinary apartments.

3. FIREPLACES. The less iron used in any fireplace, the more the fuel is immediately in contact with fire-brick; the lower its position in reference to the floor, and the more complete the control by a valve of the amount of air permitted to escape by the chimney, the more convenient and comfortable will it be found.

A large chimney having a wide opening at the top where *it terminates* in the external air, and discharging a rapid *current passing* with great force through any apartment, is a

serious evil. It is well to diminish it to a half, or even to a quarter of its area at the top if necessary.

Where the staircase and passages of a house are heated with a stove or a hot water apparatus, a comparatively mild and agreeable climate may be maintained in the different apartments.

4. VENTILATION. A general supply from the staircase or passages may be made available for the whole house. Where there is any deficiency in this respect the circulation of one apartment interferes with that of another. See pages 95 and 170.

The great object is at all times to permit an abundant ingress, but to regulate the amount that enters by the area of escape. In cases, however, where the ingress is from a high level, it may also require regulation, otherwise part of it may supply and another portion of it may discharge air.

When panels over the doors in individual apartments can be opened or shut to any extent, such an interchange between them and the staircase may be permitted as may be desirable. The staircase may in this manner be considered equivalent to the external atmosphere, care being taken to permit a continual interchange between it and the outer air, according to the demands made upon it.

When fireplaces are in operation in individual rooms they will necessarily draw from the passage and discharge by the chimneys. An aperture made into the chimney near the ceiling and protected by a valve, secures a discharge at a high level, an object of great practical importance.

If the whole space immediately below the ceiling were formed into a chamber for the admission and egress of air, a porous structure being interposed between it and the apartment, it would not give more diffusion than would be advantageous in certain conditions of the atmosphere.

A common window is abundantly ample for supplying the air required under ordinary circumstances when the air within and without is not at the same temperature; but being subject to every variety of impulse which external currents may produce, it is neither equal nor effectual in its action unless adjusted to every passing change, while on some occasions it may fail altogether in producing the amount of effect required.

A house that is supplied with an egress from each individual apartment, a general supply to and discharge from the passage, and ample diffusive arrangements for the admission of air in individual apartments, secures the most important requisites for good ventilation. To these must be added the effective *action of every fireplace* without returning smoke, and the *removal of all vitiated* air from drains, closets, dust-bins and

gas or oil lamps, where an illumination is sustained beyond that which is afforded by an ordinary candle.

5. *Gas.* The more extended use of gas, not only for illumination, but also for numerous purposes where a moderate, gentle, or local heat is required, is gradually increasing. Though, weight for weight, it is much more costly than ordinary fuel, still when the facility, rapidity and cleanliness with which it can be used are taken into consideration, it will be found on numerous occasions less expensive and much more convenient than ordinary fuel. But unless the products of combustion be carried off by adequate ventilation adapted to each burner, the same pernicious effects will arise as from coal burnt in a room without any chimney.

DRAINAGE.

The hundreds of thousands of houses in which the arrangements for this purpose are deficient, and the great progress that has been made of late years in the adaptation of effective provisions for this object, render it important that these should be very carefully examined, so as effectually to exclude all products arising from the putrefaction of animal and vegetable matter.

Formerly cesspools, or large tanks were recommended, which were in general cleaned periodically, often at very distant intervals, or connected with large drains of indifferent construction, both of which have been fitly described as reservoirs for the production of disease.

Now, however, cesspools in individual houses, drains or sewers are abolished, and, instead of large drains, small earthenware tubes or pipes are employed, the flow of water through which removes at once to the sewer all the refuse that may enter them.

The sewers, further, are placed on a much more systematic footing according to the plans now in progress. Levels are carefully attended to, and the form of the sewer, so as in the greatest degree practicable to diminish the possibility of stagnation. A system of flushing, that is, occasionally flooding each sewer with water, has also been introduced, where this additional precaution is necessary.

In densely populated districts, where the levels are not avourable, a system of pumping by steam power is adopted as *a means of compensation.*

All these measures have been resorted to after a careful *examination of* the immense extent to which disease and death

arise from the various chemical products evolved from ordinary drains and cesspools.

It should be remembered that even in cases where disease did not positively manifest itself, a low tone of health was often induced alike destructive of all comfort and capability of exertion. In country villages and in the outskirts of large towns where systematic drainage has not been introduced, the proper substitute is the formation of dry closets built of iron, stone, asphalte or other waterproof materials, and the daily addition of powdered peat charcoal, dry earth and ashes, or other absorbents of moisture such as can be obtained in each individual locality.

These arrangements, combined with a regular and systematic system of cleansing, undertaken by parties who repay themselves by the sale of the products they remove for agricultural purposes, will go far to diminish the extreme condition even of thousands upon thousands of newly-built cottages in the vicinity of the metropolis and other places.

Where measures for drainage and cleansing, such as have been described, have not hitherto been introduced, the free use of lime, chloride of lime, or muriate of zinc, and the evolution of small quantities of chlorine and nitrous acid in the apartments subject to their emanations will be found beneficial. But these alone do not give permanent satisfaction. The mass of corruption ought to be removed. With every fall of the barometer the vicinity may be flooded by the escape of offensive emanations as they are more or less relieved from atmospheric pressure.

Where a large extent of drains is loaded with decomposing debris it is important to have two apertures formed, fresh air being permitted to enter by one, and offensive gases to escape by the other. A chimney placed over the latter and the introduction of a small fire when necessary secures the discharge and decomposes the products evolved.

These brief memoranda, if connected with the elementary explanations given in the preceding pages, will show how largely chemical considerations are associated with many questions affecting the duration of human life. They might be extended in reference to the influence of Exercise, Occupations, the origin of Disease, the influence of the mind on the body, and the action and development within the living system of electrical forces that are perpetually in operation.

But in an introductory treatise it has been considered sufficient to advert to the more prominent facts that have been mentioned. The careful observer will everywhere have many opportunities of noticing peculiar phenomena that may be elucidated by an appeal to his former studies, and if he will only endeavour to look upon the world as a great laboratory in which operations are constantly in progress in unison with the laws he may have studied at home or in the class-room, he will soon learn to interpret many of the previously mysterious phenomena of nature, and apply his own knowledge to the progress of Science, Art and the Economy of Daily Life

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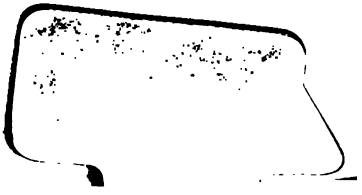
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